Abstract / Summary

Technological advances have made biology a big data discipline requiring modern computational and statistical expertise. At the same time, the post-graduate trajectories of PhD trainees have diversified to encompass a broad range of careers of which academic positions represent the minority. The mission of the Quantitative Biological Systems Training (QBIST) program is to empower biomedical researchers to choose confidently amongst a diversity of careers in the biomedical research enterprise through active training and experience in robust and transferable quantitative and leadership skills. The QBIST program will pursue 3 primary objectives. **Objective 1:** Enable trainees to develop and apply advanced computational and data science skills to complex biomedical research questions. The QBIST curriculum builds on the strengths in quantitative courses offered within the NYU Biology PhD program by increasing cohesion and continuity between courses and expanding training to include formal instruction in Data Science. **Objective 2:** Cultivate trainee skills in mentorship and leadership and provide opportunities for experiential learning through mentorship activities that promote an inclusive environment within the biomedical research enterprise. Trainees will apply and solidify newly acquired skills through the adoption of active leadership and mentoring roles in NYU’s diversity training initiatives. **Objective 3:** Enable trainees to actively explore and pursue biomedical career paths outside the traditional academic trajectory. QBIST trainees will actively explore post-graduate career options through participation in a structured internship program with non-academic organizations including science communication, non-academic research and business and entrepreneurship. To realize the three primary objectives, we will establish a QBIST workshop which will include modules that apply concepts from quantitative courses to biological examples and provide expert-led training in professional skills, building on courses established through the NYU STEP program (funded by a NIH BEST award). The QBIST program will comprise 17 faculty members with an outstanding track record of commitment to mentoring and scientific excellence with expertise in quantitative approaches to studying complex biological systems integrating molecular, cellular, and organismal biology. We will select 4 students per year for admission to the QBIST program who will be appointed for the second and third years of their PhD training. Students will be selected by the QBIST program executive committee on the basis of a written application detailing training goals and long-term career objectives. To assess the effectiveness of the QBIST program, we have designed a survey that will be completed each year by all trainees and defined new practices for tracking trainee research and career outcomes. All data and analyses will be made publically available on the QBIST web portal. Achieving the QBIST program objectives will serve to enhance the entire NYU Department of Biology PhD program and provide novel insights and resources for PhD training throughout biomedical institutions in the USA.
1. Rationale, Mission, Objectives, and Overall Training Plan

1.1 Rationale

The dramatic increase in the scale of data associated with biomedical research has prompted a reassessment of the skills required for becoming a twenty-first century biomedical researcher. At the turn of the century, the vast majority of biomedical research did not require quantitative skills. The advent of genomics, accelerated by the completion of the human genome project (Lander et al. 2001) and associated technical advances including DNA microarrays (Brown and Botstein 1999), next generation sequencing (Shendure et al. 2017), mass spectrometry (Aebersold and Mann 2016), and large-scale phenotyping (Maier et al. 2017; Ohya et al. 2005) has turned biomedical research into a computer-intensive activity requiring robust quantitative skills. Therefore, in addition to comprehensive training in cellular, molecular and organismal biology, the modern biomedical researcher now requires skills in large-scale statistical analysis and machine learning. Traditionally, biomedical PhD programs have not focused on these skills.

Figure 1. QBIST program mentors include NYU Biology faculty who have an outstanding track record of intellectual and mentoring collaborations using quantitative large-scale experimental and computational approaches to address biological problems at multiple scales.
The NYU Department of Biology (NYU Biology hereafter) is at the forefront of truly interdisciplinary, quantitative biomedical research and training. Research and doctoral training at NYU Biology is characterized by seminal contributions by PIs and trainees to understanding integrative systems and cellular biology (Ristova et al. 2016; Stolfi et al. 2015), gene expression regulation (Ciofani et al. 2012; Arrieta-Ortiz et al. 2015; Song et al. 2016; Albritton et al. 2017; Narendra et al. 2015; Neymotin, Athanasiadou, and Gresham 2014; West et al. 2018), single cell and organismal biology (Efroni et al. 2016; Zheng et al. 2018; Levy, Ziv, and Siegal 2012; Carmona-Fontaine et al. 2013), large-scale genetic analyses (Sanjana et al. 2016; Khurana et al. 2017; Poon et al. 2016; Hupalo et al. 2016), and large-scale data integration (Cheng et al. 2016). Research and training in NYU Biology integrates all levels of biology from single molecules and single cells, to tissues and organisms, through to biomes and ecosystems.

NYU Biology faculty interact closely with each other through intellectual collaboration and joint mentorship of PhD trainees (Figure 1). Several faculty have affiliations with other departments, such as the NYU Courant Institute of Mathematical Sciences, and the NYU Medical School. Additionally, NYU Biology offers a rich intellectual environment with two annual symposia on systems biology and developmental genetics, an annual retreat, a weekly departmental seminar series, annual special seminars, and informal and formal workshops on computational biology, genome sequence analysis, and proteomics that bring NYU Biology researchers together on a regular basis.

PhD training at NYU Biology is enhanced further by the rich intellectual environment in New York City. Trainees can attend courses and seminars in the wider New York City academic network, including the NYU Medical School, Rockefeller University, Columbia University, and the Memorial Sloan Kettering Cancer Center. Throughout the year, specialized groups convene meetings in the New York City area, e.g. the NY BIG meeting on bacterial biology, the Worm meeting on C. elegans, and the New York Stem Cell Coalition. Building on an extensive track record of scientific accomplishments and a highly successful history of PhD training, the Quantitative Biological Systems Training (QBIST) (pronunciation: cubist) program aims to train scientists to undertake ethical, rigorous and reproducible research that integrates cutting edge approaches in biomedical and data science to solve important problems in biology.

Concomitant with the increasingly data-intensive nature of biomedical research during the twenty-first century, the post-graduate career paths of PhD trainees have diversified (Gwynne 2006; Bonetta 2010; Robbins-Roth 2011). Whereas many PhD programs focus on training scientists within the narrow constraints of academic career progression, the reality is that the majority of biomedical PhD trainees ultimately pursue career paths outside of academia (Biomedical Research Workforce Working Group Report, NIH, 2012). Most PhD training programs take variable approaches to teaching “soft skills” and to career development and all too frequently consider activities that are not focused on research as distractions from their central mission. However, we believe that this attitude is out of step with the reality of PhD training outcomes and therefore necessitates a broadening of the goals and priorities of biomedical PhD training programs (Sinché et al. 2017). The QBIST program aims to equip trainees with robust skills in mentorship, leadership, communication, teamwork, and professional development to provide a robust foundation for subsequent careers both inside and outside the traditional academic route.

Advances in teaching research have shown that active learning and application of skills in real-world settings enhances knowledge retention and students’ abilities to creatively apply knowledge in new contexts (Freeman et al. 2014; Bonwell and Eison 1991; Bender 2012). Such active learning comprises flipped-classroom approaches, discussions, and role playing exercises, as well as formalized and structured experiences in real-world settings. A critical complement to real world experiential learning is the opportunity for self-reflection. The QBIST program will introduce (1) experiential learning by facilitating trainee mentorship of undergraduate and high school students; and (2) an internship program in which trainees will gain real-world experience in non-academic careers in the biomedical workforce. Formalized self-reflection, through writing and group discussions, will serve to enhance and reinforce these activities.

We aim to promote the development of an inclusive and diverse biomedical research workforce. Early exposure to research increases the chance that an individual will pursue graduate research (Reynolds et al. 2009; Russell, Hancock, and McCullough 2007). Therefore, to increase the pipeline of potential trainees for the entire biomedical enterprise in the USA, the QBIST program will contribute to the NYU Biology Summer Undergraduate Program (SURP), which recruits 8 minority students from throughout the United States each
year, and the NYU K-12 Applied Research Innovations in Science and Engineering (ARISE) program, which recruits 8 high school students from within New York City who are interested in Science, Technology, Engineering and Math (STEM). QBIST program trainees will participate in both of these programs as primary mentors. QBIST program mentors will actively engage in organizing and implementing activities aimed at increasing the representation of traditionally underrepresented groups.

The QBIST program will build on and expand the existing strengths of the PhD program in NYU Biology. Our analysis of PhD trainee career trajectories over the past 15 years has determined that NYU Biology PhD graduates pursue a wide diversity of careers within the biomedical research enterprise after completing training. Of the 121 trainees who successfully completed their PhD, 53% progressed to a postdoctoral position in an academic institution. The majority of former trainees remain in postdoctoral positions; 20 individuals (17%) now run research laboratories in academic positions. Trainees who did not continue in academia pursued a wide variety of career paths that include the pharmaceutical industry (15; 13%), publishing (5; 4%), and consulting (9; 7%). The trends identified in our study of PhD trainees are largely consistent with trainee career trajectories reported for a large cohort of US PhD students (“Nsf.gov - NCSES Survey Doctorate Recipients: 2015 - US National Science Foundation (NSF)” n.d.). Although there is a clear need for both i) integrated training in biomedical research and quantitative science and ii) the development of skills that prepare PhD trainees for a variety of careers (Aikens and Dolan 2014), the solutions to these challenges are not self-evident. Therefore, the QBIST program will test and assess the effectiveness of new activities aimed at addressing these needs using surveys and external and internal mechanisms of assessment. To make the outcomes of the QBIST program widely available, we will adhere to the policies of transparent data reporting of graduate programs (Blank et al. 2017) and make all data available through our program’s website, the QBIST web portal (https://wp.nyu.edu/qbist/). As the program evolves, we will compile the aggregate results of our assessments for publication in academic journals to ensure that the outcomes of our program are available to the wider academic community, thereby contributing to the national effort of enhancing the doctoral training experience.

1.2 Relationship to other NIH training programs at NYU

NYU comprises an undergraduate research institute and a medical school, which are located at distinct locations in Manhattan separated by approximately 2 miles. NYU Biology, which is within the College of Arts and Sciences (CAS) has not previously held an NIGMS-funded training grant and no department in CAS is supported by an NIGMS T32 (Table 3). The Training Program in Development Genetics (5T32HD007520; PI Jessica Treisman, Skirball Institute; NICHD) is jointly held between The Skirball Institute at the NYU Medical School and NYU Biology. The Training Program in Developmental Genetics focuses on developmental biology and has an established track record of excellence in graduate training. A small number of NYU Biology PhD trainees (~1/year) have been supported by this program. Thus, the QBIST program will benefit from the institutional knowledge of participation in a successful NIH-supported training program.

Simultaneous with this submission, an application entitled the “Chemistry-Biology Interface Training Program” (CBITP) has been submitted to NIGMS. The directors of the CBITP proposal, Professors Paramjit Arora and Nathaniel Traaseth are faculty in the NYU Department of Chemistry. The QBIST program will operate in parallel with the CBITP. The QBIST program directors (Gresham and Vogel) and QBIST program mentors (Ghedin, Bonneau, and Carmona-Fontaine) are participating faculty in the CBITP. However, the training goals and activities of the CBITP are entirely separate from this application.

As the Biology Department and Chemistry Department are both within CAS and thus administered by the same Dean, the QBIST program and CBITP will seek to create administrative and training efficiencies. To this end, the QBIST program directors (Gresham and Vogel) and CBITP directors (Arora and Traaseth) will meet annually to share information regarding administration of the two programs. Moreover, we will endeavor to share resources, as exemplified by our joint organization and participation in a National Mentoring Resource Network (NMRN) faculty mentor training workshop held in April, 2018. Scientifically, the Biology and Chemistry departments engage in regular intellectual exchange through a monthly “Chemical Biology” seminar series with speakers from both departments as well as occasional day-long symposia.

Although CAS and the NYU Medical School are in distinct locations and are administratively independent, there are strong intellectual and training ties between the two entities. Synergies with T32 programs at the NYU Medical School will be realized through formal scientific interactions (e.g. conferences, seminars and
symposia) and participation in ongoing career training activities (e.g. “What can you do with a PhD?” workshops). Dr. Christine Ponder (Director, Office of Postdoctoral Affairs) leads joint training courses with the NYU CAS and NYU Medical School for career development skills and the QBIST program will build on these successful activities.

1.3 Mission
The central mission of the QBIST program is to empower biomedical PhD trainees to choose confidently amongst a diversity of careers in the biomedical research enterprise through active training and experience in robust and transferable scientific, quantitative and leadership skills. We aim to make formal training in biology and data science truly integrated through a cohesive, expanded curriculum. We will cultivate essential skills in leadership and mentorship among trainees through structured training while actively working to increase the representation of traditionally underrepresented groups in scientific research. Our goal is to provide comprehensive career preparedness by facilitating meaningful exposure to the diversity of career options available within the biomedical research enterprise.

Figure 2. The QBIST program will introduce four new activities: i) a unifying workshop, ii) an integrated quantitative curriculum, iii) a structured mentoring experience and iv) a non-academic internship program that build on the existing strengths of the NYU Biology PhD program to realize the QBIST program mission.
1.4 Objectives

Building on the long-standing and successful record of PhD training in NYU Biology, the QBIST program seeks to address the need for 1) improved quantitative training of biomedical trainees and 2) enhanced training in broadly applicable skills to facilitate career preparedness. Building on our record of success in PhD training, we will introduce four key new activities (Figure 2) aimed at attaining the following objectives:

Objective 1: Enable trainees to develop and apply advanced computational and data science skills to complex biological research questions. We are convinced that strong quantitative skills are essential for twenty-first century biomedical research and represent readily transferable skills applicable to many career options. Therefore, we will provide trainees with robust training in quantitative biology and data science. To meet this objective, we will implement an integrated quantitative biology curriculum. The curriculum will build on existing strengths of the NYU Biology PhD program to provide cohesive and sequential training in statistical analysis, genomics, systems biology, and data science. Trainees will actively apply these skills in dissertation research projects. Formal training will be reinforced through group discussions of seminal and current research papers focused on systems level analyses of biomedical problems.

Objective 2: Cultivate trainee skills in mentorship and leadership and enable experiential learning through mentorship activities that promote an inclusive environment within the biomedical research enterprise. To meet this objective, we will implement the QBIST workshop, which will provide formal training in mentorship, leadership and career development skills through instruction, role play, hands-on exercises and discussion forums. Skills that will be emphasized include mentoring, leadership, project management, job applications and interviewing, and science communication. Elements of the QBIST workshop build on existing courses offered at NYU through the NYU Science Training Enhancement Program (STEP), funded by an NIH Broadening Experiences in Scientific Training (BEST) Award. However, the QBIST workshop will serve to introduce these skills early in PhD training to enhance opportunities for their application and reinforcement throughout the PhD training experience. Trainees will apply mentorship and leadership skills through active participation as mentors in the NYU Biology Summer Undergraduate Research Program (SURP) or NYU K-12 ARISE program. As both the SURP and K-12 ARISE programs provide opportunities for traditionally underrepresented groups to participate in research, QBIST program trainees will directly contribute to enhancing diversity among biomedical trainees. As described in the Recruitment Plan to Enhance Diversity and Trainee Retention Plan, we believe that these efforts will contribute to fostering recruitment and retention of a diverse population of doctoral trainees.

Objective 3: Enable trainees to actively explore and pursue biomedical career paths outside the traditional academic trajectory. To meet this objective, we will provide formal instruction in “soft skills” that are required in the professional workplace, such as communication, teamwork and management, through the QBIST workshop. Trainees will have the opportunity to gain meaningful exposure to the rich diversity of career options available to them through an internship program with organizations in New York City in which students will spend a six week period working full time in a non-academic position.

The QBIST program will meet these three objectives by introducing four new activities (Figure 2) that represent innovations in training and mentorship while maintaining a commitment to excellence in systems and integrative biological research (Figure 1).

1.5 Overall training plan

The QBIST program will operate within the NYU Biology PhD program. QBIST program trainees will be members of NYU Biology and the expectations will be consistent with current PhD training objectives including all curricula and research requirements. Below we describe the activities of trainees in the NYU Biology PhD program, the new activities that the QBIST program will introduce, and how they will benefit the entire PhD program. Trainees will participate in the QBIST program during years 2 and 3 of the Biology PhD program (Figure 3).
1.5.1. The NYU Biology Department PhD Training Program

The existing PhD program in the NYU Department of Biology entails the following specific elements (Figure 3): **Laboratory Rotations**: During their first year, PhD students spend three nine-week periods (rotations) in three different laboratories. These short-term research experiences allow students to become familiar with the topics studied and methods employed in the lab, and determine whether the lab’s interests are aligned with their own research and training goals. During rotations, students participate in all laboratory activities including lab meetings, journal clubs, and individual meetings with the PI of the lab. Trainees typically work under the close supervision of either the PI, a senior postdoctoral fellow or PhD trainee. At the end of their rotation, trainees present their results to the entire laboratory at a lab meeting. Upon completing the rotation, each student is provided with a written assessment by the PI giving formal feedback on the performance of the student. The three required laboratory rotations are invaluable to allow trainees to make an informed decision about the laboratory in which they will ultimately pursue their dissertation research.

**Core Curriculum**: All PhD students are required to take a minimum of seven courses, which are typically completed within the first three years. The core curriculum comprises:

**Year 1**
- Biocore III: Molecules and Cells: A paper reading class focused on critical reading of primary literature
- Biocore IV: Genes, Systems and Evolution: A paper reading class focused on critical reading of primary literature
- The Art of Scientific Investigation: Instruction in science communication and ethics
- Responsible Conduct of Research (see attached Plan for Instruction in the Responsible Conduct of Research and syllabus in Appendix B; repeated every 4 years)

**Years 2 and 3**
- Statistics in Biology
The NYU Biology PhD program has a long and successful history of developing trainees' quantitative skills through curriculum offerings. Since 2014, Statistics in Biology, which provides an introduction to statistical computing using R, has been a required course for all students. Students have the choice of additional quantitative courses when selecting electives and an increasing number of students choose to do so reflecting the increasing demand for quantitative skills.

The curriculum has been designed to minimize the required coursework and maximize the time that can be devoted to research while still addressing the most important training needs (Aikens and Dolan 2014). Moreover, the diversity of graduate level courses enables students to individualize their course work as appropriate for their interests and training goals. The curriculum requirements for QBIST program trainees will be identical, but will entail a specified sequence of classes as described below. All instructors incorporate topics relevant to methods for enhancing rigor and reproducibility (see attached Plan for Instruction in Methods for Enhancing Reproducibility) as part of formal instruction.

Qualifying Examination: The PhD qualifying examination is held at the end of the first year of full-time enrollment in the PhD program. The exam consists of two parts: a written research proposal and an oral presentation of the proposal, which the trainee defends before a committee comprising three faculty members who have not yet worked with the student (i.e. in a rotation) to ensure unbiased evaluation of the student’s proposal. A stipulation of the proposal is that it must not be in the area of the student’s potential thesis research or past research. This ensures that all trainees are assessed on their ability to master a new subject via self-directed learning. The examination assesses the trainee’s skills in scientific reasoning, analysis, writing, interpretation of data in the literature, integration of scientific concepts, and creativity in the design of new experiments and analyses. On the basis of both the written and oral presentations, the committee determines whether the student has fulfilled the criteria. Students who fail to fulfill the criteria of the qualifying exam can revise the proposal and presentation based on the committee’s recommendations, and retake the exam within a two-month period before the same committee. Students who pass the qualifying exam and fulfill all other requirements of the program select a faculty mentor who supervises the doctoral research. Those students who do not successfully pass the qualifying exam upon the second attempt exit the program and are granted a Master of Science (MS) degree.

Dissertation Proposal: By April 1st of their second year in the PhD program, students form a thesis advisory committee comprising the doctoral supervisor, three faculty members from within the department who have agreed to oversee the dissertation research, and one external faculty member, typically from a different institution. A dissertation proposal, written in the format of an NIH R01 proposal, is presented to the thesis advisory committee and defended orally before the end of the second year. The primary purpose of the thesis advisory committee is to provide feedback on the dissertation proposal, taking into account the scientific merit, feasibility, and originality of the research. Following a successful dissertation proposal, students proceed with mentored research.

Dissertation Research: Dissertation research is undertaken during years 2-6 of the PhD program. Research is typically performed under the mentorship of a single faculty mentor; however, at least one student per year elects to pursue dissertation research under the mentorship of two PIs, reflecting the collaborative nature of faculty at NYU Biology (Figure 1). In general, trainees meet with their faculty mentor weekly to discuss results and research plans, and attend lab meetings in which they present their work to other lab members.

Graduate Student Seminar: Following completion of the dissertation proposal, every PhD trainee presents their research progress once a year in a weekly Graduate Student Seminar. The weekly Graduate Student Seminar is attended by all faculty and PhD students. Students are assigned a faculty host with whom they meet prior to the seminar to receive feedback on their presentation. The faculty host is typically not a member of the thesis committee and thus able to provide a fresh perspective on the research and its presentation. Presentations last for 30 minutes. Afterward, the student receives written feedback from the faculty host on the presentation content, slides, and delivery. Participation in the Graduate Student Seminars provides important training in public speaking and presentation skills and thus is an essential component of career development training.

Annual Dissertation Committee Meeting: For the duration of the dissertation research period, an annual dissertation committee meeting is held at the end of each academic year. Prior to the meeting, the PhD student
provides the committee with a written summary of research progress and plans for the coming year. The student presents progress towards their dissertation research as well as their immediate research goals at the meeting to the entire committee. The committee meeting serves two primary functions: 1) to ensure that the PhD trainee is getting the most out of their training experience and 2) to provide feedback on results and progress towards completion of the dissertation research. To fulfill the first function, each dissertation committee meeting entails an initial meeting between the trainee and committee without the faculty mentor. This enables the trainee to convey any issues they have encountered working with the supervisor that they would like help in addressing. Committee members also serve this function by being available throughout the year. To fulfill the second function, the trainee presents research results generated during the previous year in a highly interactive presentation format. At the conclusion of the meeting, the committee provides recommendations for research and related activities (e.g. papers, courses and conference attendance) for the coming year.

**Doctoral Dissertation:** Each PhD trainee completes a doctoral dissertation detailing research undertaken during the training period. The dissertation must represent original, independent research in a significant area of biology at a level comparable to research published in recognized journals. When the dissertation is completed and has been approved by the faculty mentor and by the dissertation committee, the candidate defends the results of the research before the dissertation committee. This entails a one-hour public presentation of the results of the thesis research and a closed door defense with the committee that can last up to two hours. Successful written and oral presentation of the research and defense of the research results in the student being awarded a PhD.

**Research expectations:** Although there are not specific requirements regarding research output, trainees are provided with guidelines regarding peer-reviewed publications and attendance at scientific conferences. In general, students attend at least two national and international conferences during their PhD training, but frequently more. Support for conference attendance is provided by both the Graduate School of Arts and Sciences ($1,000/trainee over the course of their training) and by the Department of Biology ($500/trainee/year throughout their training). In general, students are expected to publish at least one first author paper describing the results of their dissertation research in a peer reviewed journal. Over the past 15 years, NYU PhD trainees have published a median of three papers during their doctoral training of which they are primary author on median of one paper.

1.5.2. New QBIST Program Activities

Trainees selected for the QBIST program will participate in QBIST program activities during the second and third years of enrollment in the PhD program (Figure 3). In addition to completing all elements of the NYU Biology Department PhD program described above, QBIST program trainees will participate in four QBIST program specific activities with the goal of addressing our three objectives.

**QBIST Program Activity 1: The QBIST Workshop**

To provide an overarching framework for the QBIST program, we will organize and convene the QBIST workshop. Participation in the QBIST workshop will be required for trainees supported by the QBIST program training grant but will also be open to all second and third-year NYU Biology PhD students. The purpose of the QBIST workshop is to bring the elements of the QBIST program together in a unified way, introducing the program’s aims to provide comprehensive training and support in skills required for professional development and to enable trainees to confidently apply quantitative skills to biological questions. The QBIST workshop emphasizes training through active student involvement. Deviating from the traditional lecture-based model, it will primarily consist of activities and discussions. Students will be encouraged to apply acquired knowledge to their own research and training experience. The entire QBIST Workshop syllabus is provided in Appendix A.

The QBIST workshop modules include:

1. **Aligning expectations.** At the beginning of the academic year, QBIST program directors Gresham and Vogel will meet with the entire QBIST trainee cohort. The meeting will serve to convey information on the program and expectations of QBIST trainees. Trainees will complete the QBIST program survey during this first meeting. The meeting will place emphasis on explaining the rationale behind the primary aims of the QBIST program to provide QBIST trainees with robust quantitative skills and the necessary skills and empowerment to manage their career development.
2. **Training in diversity issues and inclusion.** Trainees will broaden their perceptions of diversity and inclusion through a workshop led by Professor Fatiah Touray (NYU Assistant Dean for International and Diversity Advising). Professor Stephen Small (NYU Biology) and Professor Susan Anton (Director for Faculty Diversity, Equity, Inclusion and Development) will then lead discussions on the value of promoting diversity in academia and opportunities for students to engage in ongoing efforts to increase inclusion: summer programs including SURP and K-12 ARISE programs, student conferences for underrepresented groups, and direct contact with high schools and colleges with a high enrollment of students from underrepresented groups. QBIST trainees will be strongly encouraged to participate in at least one of these programs and to discuss their experiences within the QBIST workshop. Numerous opportunities for such interactions are already well-established, as outlined in the *Recruitment Plan to Enhance Diversity* and the *QBIST workshop* syllabus (Appendix A). For example, they include visits to the Annual Biomedical Research Conference for Minority Students (ABRCMS) and Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) conferences and to ethnically and socioeconomically diverse colleges and high schools including John Jay College (NY); Pace University (NY); SUNY Farmingdale (NY); New York Institute of Technology (NY); Borough of Manhattan Community College (NY); University of Houston-Downtown (TX); Winston-Salem State University (NC); North Carolina A&T (NC); Explore Charter School in Brooklyn; and Forsyth Satellite Academy, Manhattan.

3. **Training in leadership, teamwork, and project management.** This module introduces trainees to essential elements of leadership, teamwork, and project management skills, with the aim of i) preparing QBIST trainees for both their PhD and internship experience; and ii) equipping trainees with transferable skills applicable to a broad range of careers in both academic and non-academic settings.

4. **Training in mentoring.** This module is designed to facilitate students’ maximization of their own mentored training experience during the PhD program and to provide essential mentoring skills that prepare trainees for their participation as mentors in the SURP and K-12 ARISE programs (Activity 3). The module will be led by Dr. Christine Ponder (Director, NYU Office of Postdoctoral Affairs) and Professor Christine Vogel (QBIST Program Director).

5. **Training in science communication.** This module focuses on writing for the interested lay person. It is aimed at training students for internships involving writing (e.g. with publishers) and science communication. This module will be led by QBIST Program Director, Professor David Gresham (who is a former Associate Editor at *Nature Genetics*) and Professor Stephen Hall (NYU Journalism).

6. **Surveying and evaluation.** This module builds on the expertise provided by Professor Sue Kirch (Associate Professor, NYU Department of Teaching and Learning) who will train students in survey design and evaluation. QBIST trainees will evaluate responses to the Annual QBIST Survey to assess the successes and challenges of the QBIST program, and also assess the effectiveness of the survey itself. Students will also apply these skills to expanding the Individual Development Plans (IDP) that they have crafted with their respective QBIST program mentors. Students will evaluate the effectiveness of the IDPs as part of the survey questions and provide direct feedback to the QBIST program directors on recommended changes, rendering the program transparent and proactive with regard to involvement of all participants.

7. **Internship application and interviewing skills.** This module will prepare students for applying to internships as described in Activity 4. Dr. Christine Ponder (Director, Office of Postdoctoral Affairs) and the QBIST program directors Gresham and Vogel will work with trainees to identify interests outside of academic career paths, evaluate possible internship options, and prepare them for application writing and interviews in a targeted and applied manner.

8. **Training in methods to increase rigor and reproducibility.** This module will provide a framework for methods to enhance rigor and reproducibility in experimental and computational research. Trainees will review Best Practices Guidelines for NYU Biology (see Plan for Instruction in Methods for Enhancing Reproducibility) and discuss case studies.

9. **Foundations and advances in systems biology.** This module will enable trainees to be truly “bilingual” in quantitative and biological skills. It comprises multiple sessions in which instructors from the integrated quantitative curriculum lead a discussion of a publication or dataset reinforcing concepts and skills covered in their respective courses. Each session will be led by two instructors from the integrated quantitative curriculum (Activity 2) facilitating cross-course integration and interaction.

Modules 3, 5, and 7 take elements from well-established and highly successful courses that are part of the NYU STEP program (see Career Development). Modules 2 and 5 incorporate elements from training
developed for the SURP program. Although some of the elements of the QBIST workshop are currently available to NYU students, they are offered in disparate and disconnected courses and workshops. By offering exposure to topics including mentoring, diversity, leadership and career development at an early stage, QBIST program trainees will be well placed to pursue advanced training on topics that are of particular relevance to their career plan through the rich resources available at NYU.

QBIST Program Activity 2: Implement an integrated quantitative curriculum to equip trainees with broadly applicable skills in quantitative biology and data science.

To specifically address the first objective of the QBIST program - enable trainees to develop and apply advanced computational and data science skills to complex biomedical research questions - trainees in the QBIST program will follow a defined curriculum that aims to provide comprehensive training in statistics, computer programming and data science. QBIST program trainees will take a structured series of classes in years 2 and 3. This series of sequential classes is designed to provide a robust foundation in modern statistical computing and its application to biological research, thereby expanding the training traditionally offered in biology PhD programs. Whereas the first three courses are currently offered by NYU Biology, the QBIST program will introduce the course "Big Data," offered in the NYU Center for Data Science, to the curriculum in which trainees will gain broad exposure to advanced Data Science and its application across a broad range of domains.

The series of sequential classes (see Appendix A for representative syllabi) that will be taken by all QBIST program trainees is as follows:

- **Statistics in Biology** (Primary Instructor: Kristin Gunsalus): The goal of this course is to develop skills in statistical analysis, hypothesis testing and data analysis.
- **Applied Genomics** (Primary Instructor: David Gresham): The goal of this course is to acquire skills in the application of statistical programming and visualization methods for the analysis of genome scale data.
- **Machine Learning and its Applications in Biology** (Primary Instructor: Rahul Satija): The goal of this course is to provide instructions in common methods of supervised and unsupervised statistical learning.
- **Big Data** (Primary Instructor: Juliana Freire): The goal of this course is to provide instruction in large-scale computational analysis and its application to diverse academic and non-academic disciplines.

The material, skills, concepts, and principles covered by these courses will be unified through the following:

1. All instructors will meet annually to discuss syllabi, learning objectives and cohesion among courses. Student feedback from course evaluations will be addressed during the meetings and strategies for addressing and mitigating issues identified by students will be proposed and implemented.
2. Instructors will aim to use common example studies across courses to enable analysis from various angles and with increasing complexity and sophistication. For example, all courses will make use of data generated through the The Cancer Genome Atlas (Hutter and Zenklusen 2018) with respect to main questions, data generation, analysis approaches, results, and impact. The use of a common dataset will be enabled by the centralization of large-scale datasets on the NYU High Performance Computing Cluster.
3. As part of the QBIST workshop, trainees will meet in semesters 2 and 3 of their appointment for the modules in “Foundations and Advances in Systems Biology” designed to promote and enable trainees’ real world application of data science skills to integrative biological research.
4. Programming assignments will require exclusive use of R, a commonly used programming language in genomics and data science. Computer programming resources provided in class will be supplemented with workshops provided through NYU library data services and additional online resources, including Lynda courses (through NYU libraries), Datacamp (https://www.datacamp.com/) and the NYU Gencore Learn Site (https://learn.gencore.bio.nyu.edu/), which provides detailed information on computational approaches for analyzing biological data.
5. As outlined in the Plan for Instruction in Methods for Enhancing Reproducibility, mentors and instructors will promote reproducible experimental and computational research using computational notebooks such as R markdown documents and Jupyter Notebooks. All courses and projects will require common and consistent practices for version control using git and github, backups, and rigorous statistical testing.
QBIST Program Activity 3: Experiential learning in mentorship through trainee participation as mentors of junior researchers.

To specifically address the second objective of the QBIST program - **cultivate trainee skills in mentorship and leadership and enable experiential learning through mentorship activities that promote an inclusive environment within the biomedical research enterprise** - we will provide formal training through the QBIST workshop in diversity, inclusion, leadership, management, communication, teamwork, and mentoring. Trainees will apply these skills in the summer of their second year by participating as mentors in programs that aim to enhance the representation of traditionally underrepresented groups in the biomedical workforce. The QBIST workshop will enable reflection and assessment of this experience, thereby enhancing the experiential learning process.

One opportunity to apply mentoring and leadership skills will be through participation in the highly successful **NYU Biology SURP**. The NYU Biology SURP was initiated in 2016 with the express goal of providing authentic research experience for undergraduate students from traditionally underrepresented groups (also see **Recruitment Plan to Enhance Diversity**). Of the 24 participants admitted to SURP from 2016-2018, 33% were African-American and 29% were Hispanic. Fifty-two percent were the first in their families to attend college, and 63% were female. Four former SURP participants have already enrolled in PhD programs; one is in a Postbaccalaureate Research Education Program; and one transferred to an Ivy League institution to finish her undergraduate degree. In 2017, a former SURP student was accepted to the NYU Biology PhD program but declined the offer. SURP students receive travel and housing support, a living stipend, and an opportunity to participate in independent research under the guidance of a mentor.

**One the of key elements of QBIST trainee participation in SURP will be placement of students into leadership roles.** QBIST trainees will receive detailed guidance from SURP co-ordinators, Professor Stephen Small (NYU Biology) and Professor Andreas Hochwagen (NYU Biology) but will assume considerable responsibilities including consideration and selection of SURP applicants; research project design and oversight; and coordination and participation in additional training and social activities for SURP students. As a result, QBIST program trainees will be empowered through responsibility and ownership of the effort, and able to put mentoring and leadership skills into practice.

The second program in which trainees can function as mentors is the highly successful **NYU K-12 ARISE program** in which NYU Biology has been participating since 2014. As with the NYU Biology SURP, QBIST program trainees will receive mentor training and will help with student selection. K-12 ARISE participants come primarily from underrepresented groups and include high school and middle school students from New York City. NYU Biology has so far mentored 32 students of which 9 came from underrepresented groups and 24 were female. The program has been highly successful: several junior researchers have continued their work in the labs after completing the program in the summer and others are now undergraduate students at a variety of colleges. Letters of support from the director of the SURP (Stephen Small) and K-12 ARISE (Ben Esner) programs have been received but, are not included with this application due to page limits of appendices.

QBIST Program Activity 4: Implement a formal internship program to enable real-world learning in careers within the broader biomedical enterprise.

To specifically address the **third objective** of the QBIST program - **enable trainees to actively explore and pursue biomedical career paths outside the traditional academic trajectory** - we will implement an internship program in non-academic careers. During the summer of their third year, QBIST program trainees will be provided with an opportunity to undertake a ~6 week internship in a non-academic professional environment. The intention of this experience is to:

1. Gain exposure to careers in the biomedical workforce that broaden perspectives on career trajectories
2. Expand trainees’ professional networks
3. Provide an opportunity to apply skills in biological research and data science
4. Apply skills in mentoring and leadership in a non-academic environment
5. Enrich overall training experience through involvement in real-world settings

With these goals in mind, we have engaged several organizations who have agreed to participate in our internship program across five primary domains (please see **Letters of Support**):

- Pharmaceutical Industry: Regeneron
- Non-academic research: New York Genome Center
Although we have established a foundation of participating organizations, internship opportunities will not be restricted to these partners. We will encourage program trainees to seek out and secure internships with other organizations in New York City that will serve to enhance their career development.

Trainees will be provided financial support through the QBIST program and thus the internship program does not require a financial commitment from internship partners, trainees, or their doctoral supervisors. The QBIST Workshop will serve to ensure that trainees are prepared for their internship experiences through:

- Discussions centered on internship options, development of application materials, and interviewing skills
- Targeted training in leadership, management, and communication skills
- Discussions focused on trainee expectations and goals for the internship
- Provision of pertinent information received from the internship provider

To facilitate self-reflection, all trainees will maintain a journal for the duration of their internships. They will summarize their positive and negative reflections with respect to the impacts of their internships on career preparedness. Following completion of internships, trainees will receive written feedback from their direct supervisor at the internship organization. Students will share their experiences as part of the QBIST program final year evaluation, and will provide written summaries of their experiences.

1.6 Trainees’ background

The NYU Department of Biology has a strong track record of attracting high quality PhD trainees. Over the past 5 years, we have received an average of 229 applications to the PhD program each year (Table 6A). Typically we make between 30-40 offers of admission and admit between 11-14 students per year. The selection of PhD trainees is outlined in the Recruitment Plan to Enhance Diversity.

To maximize the impact of the QBIST program and the efficiency of the training, QBIST program trainees will not be required to have a specific background in quantitative analysis or computer programming, but will be asked to describe their motivation for obtaining such skills (see Trainee Appointment Procedures in Appendix D). This motivation is expected to be inspired by biological questions and technologies and will be assessed by the QBIST Executive Committee.

All QBIST program trainees will be required to adhere to the curriculum requirements of the NYU Biology PhD program and the QBIST program. Trainees with advanced quantitative skills will be paired with students with a weaker quantitative background to enhance learning experiences and create peer-to-peer teaching opportunities. Pairings will be chosen by the respective course instructor and will be discussed during meetings of the QBIST Executive Committee.

Diversity of NYU Biology PhD Program. The current PhD student body at NYU Biology is diverse with respect to gender, racial, and social backgrounds. Over the last 5 years, 59% of admitted students have been female and 19.2% are from underrepresented racial groups. We are committed to increasing diversity at all levels through a variety of activities. For example, in 2016 NYU Biology appointed Professor Stephen Small as the NYU Biology Diversity Representative. Professor Small coordinates efforts such as the SURP and annual participation in the ABRCMS and SACNAS conferences. As the Department has been participating in these conferences, the applicant pool has increasingly diversified. In the 2017 application cycle, 44 out of the 220 applicants self-identified as belonging to a racially underrepresented group. Overall, 132 applicants (60%) were female. Of the current student body at NYU Biology, 16% of individuals from underrepresented groups (including female and racially diverse students) received awards or fellowships.

The Recruitment Plan to Enhance Diversity and Trainee Retention Plan describe how the QBIST program will continue, and expand, existing efforts to increase recruitment and retention of individuals from underrepresented groups.
1.7 Effect of training activities on other trainees in the NYU Biology PhD program

We anticipate that the proposed training activities associated with implementing the QBIST program will have a broadly positive impact on other trainees in the NYU Biology PhD program. Specific steps that will be taken to ensure these activities have a positive impact include:

- All courses will be offered to all NYU PhD students, including the QBIST workshop.
- Mentoring experiences such as participating in the SURP or K-12 ARISE program are available to all PhD students.
- Courses comprising the quantitative curriculum are available to all trainees as electives.
- The “Science Lives” informal seminar series is open to all members of the department as it provides an opportunity to broaden students’ horizons with regard to academic and non-academic career paths.
- We will work to expand our network of internship opportunities. Using the experience of the QBIST program as a pilot, we anticipate providing internship opportunities to all PhD students in future years.

2. Career Development

Innovation in career development is a primary focus of the QBIST program training plan. Our three objectives contribute directly to career development in the following ways: 1) promoting broadly applicable quantitative skills in biology that are relevant for a wide range of possible careers (Objective 1); 2) formal training in leadership, management, communication, and mentoring through the QBIST workshop, and opportunities to apply knowledge in a variety of contexts that will facilitate essential experience in mentor-mentee relationships (Objective 2); and 3) real-world experience in non-academic careers in the biomedical enterprise through an internship program (Objective 3).

Importantly, new activities that promote career development advance the overall NYU Biology PhD program in two specific ways. First, all PhD trainees will have access to the QBIST program activities, including the QBIST workshop, the mentoring and the internship experience. Second, the career development activities are introduced early in the trainees’ tenure to ensure career development is an ongoing focus throughout the PhD experience and the trainee can effectively make use of resources at NYU including courses and other training.

New activities build on a foundation of diverse efforts to promote career development as part of the NYU PhD Biology program. Below, we describe how existing activities that facilitate career development will be integrated with efforts initiated in the QBIST program. All information regarding career development resources and outcomes will be made available on the QBIST web portal and will be maintained and updated annually.

2.1 Existing career development activities available to NYU Biology PhD students

2.1.1 NYU Science Training Enhancement Program (STEP)

The NYU STEP Program led by Dr. Christine Ponder and Professor Carol Reiss (NYU Biology) provides training for graduate students and postdoctoral fellows in preparation for a variety of careers in biomedical research. The NYU STEP Program was established with support from the NIH BEST program (Award 5DP7OD018419; Budget Period: 20-SEP-2013 - 31-AUG-2018). Essential elements established by the program including courses led by Dr. Ponder, will continue after the grant end date through support provided by NYU (see letter of support from Dean for Science, Michael Purugganan in Letters of Support).

Hope is Not a Plan. The NYU STEP offers a course focused on career development called “Hope is Not a Plan: Taking Charge of Your Science Career.” This course is intended for graduate students who have passed their qualifying exams and postdoctoral scholars. Participants have the opportunity to evaluate their own values and interests as they relate to their professional careers through an introduction to four career tracks: For-profit Industry, Non-profit and Government, Communications, and Academia. Trainees are asked to identify skill areas they would like to develop in the NYU STEP program. The course meets for 90 minutes once a week for 8 weeks and covers the following topics: identifying career objectives using an Individualized Development Plan (IDP); setting career goals; career paths for PhD trainees; job search; resumes and interview skills; negotiating a job offer; and practice interviews. The course is very successful. Exit surveys from the 2016 and 2017 courses showed that 71% of the students would recommend the course to a colleague (another 27% said maybe, only 2% would not recommend). In a follow-up survey administered 3 years after
the first year the course was offered, 72% of past participants indicated that the course was helpful in clarifying their career goals, and 85% of those in new jobs indicated that the course helped them transition into their next position.

**Relationship to QBIST workshop.** Although the “Hope is not Plan” course provides successful and detailed career development training, we have found that trainees disproportionately take the course late in their training (year 5). Moreover, as the course is voluntary and offered at the institutional level, it is taken by a minority of NYU Biology PhD students. Therefore, we will integrate select elements of the course (e.g. interviewing skills) into the QBIST workshop to provide career development training early in the student’s tenure thereby addressing recommendations on early interventions to maximize the student’s training experience (Schmidt and Clark, 2017).

**Additional courses promoting career development.** A number of additional courses are offered intermittently through NYU STEP to facilitate trainee development of specific career skills including:

- **Drug Development:** Introduces students to the process of launching one’s own drug development project from target selection through experimental testing, as well as biomedical career options in this field
- **The Business of Science:** Focuses on the enhancement of communication, leadership, and team building skills necessary to develop successful applications for a variety of positions
- **Virtual Networking:** Introduces students to the process of building a successful profile and resume
- **Venture Creation in the Biomedical Industry:** A project-based course centered on developing viable business models within the biomedical research enterprise
- **Science Diplomacy:** Explores the various sectors, agencies, challenges, and career opportunities for scientists within the field of international diplomacy. The course emphasizes 4 primary themes: science Diplomacy through government, science diplomacy through academia, science diplomacy through institutions, and science diplomacy through media
- **Medical Communications Course:** Facilitates the evaluation and development of interests and skills in non-academic career paths that involve medical writing
- **Project Management:** Introduces students to 4 distinct phases of project development: introduction and initiation, planning, implementation and control, and close out
- **Academic Writing:** Presents principles of academic writing, including papers, proposals, book chapters and dissertations
- **Best Practices in Teaching and Learning:** Focuses on course planning and preparation, effective instruction, and assessment of student performance
- **Effective Communication:** Walks students through the norms and challenges of professional email etiquette and practices

### 2.1.2 The Annual Biology Departmental Retreat

NYU Biology holds an annual retreat attended by all graduate students, postdoctoral researchers and faculty. The retreat is organized entirely by graduate students (with administrative support from the department), providing trainees with experience in organization and logistics. The retreat is held at the beginning of the academic year to welcome the incoming class of PhD trainees to the department. Additionally, the retreat serves the essential function of promoting department cohesion through poster presentations, science talks, and informal games and social activities. NYU Biology faculty and PhD program alumni also give talks on topics related to career development.

Specifically, each retreat includes: 1) an informal interview with faculty members on their career trajectories; 2) a presentation from a current faculty member on their own graduate school experience; and 3) a presentation from an alumnus describing their career path following graduation from the NYU Biology PhD program. Recent speakers have included Dr. David Dahdal, Director of Medical Affairs, Scientific Training & Publications at Ferring Pharmaceuticals; Dr. Nathalie Velarde, Chief of Asia-Pacific Programs and Science Advisor, Homeland Security; Dr. Matthew Nelson, Assistant Professor, St. Joseph’s University; and Dr. Magdalena Leszczyniecka, President and CEO of STC Biologics. Hearing about the variety of possible career paths pursued by recent NYU Biology PhD graduates provides an invaluable opportunity for trainees to reflect on their own possible careers while cultivating a network of alumni.
2.1.3 NYU Wasserman Center for Career Development

NYU provides broad support for career development for all students, including graduate students, through the Wasserman Center for Career Development. In preparation for seeking employment, the Wasserman Center has career coaches who provide professional, individualized career guidance and support throughout the career exploration process. Career coaches help trainees identify professional interests and goals, and discuss job search strategies. The Wasserman Center maintains an online database that gives students direct access to search for full-time, part-time, and internship positions. The Center hosts hundreds of career-related events and several career fairs each year that help students explore different industries, learn about career options, and network with employers. On-Campus Recruitment is an opportunity for NYU students to interview on campus for competitive full-time jobs. Organizations from a wide variety of for-profit and nonprofit industries recruit students through the program.

2.1.4 Instruction in teaching and mentoring

NYU Biology PhD students have numerous opportunities to gain experience as educators by working as teaching assistants for a wide variety of courses offered by the department. Teaching is not required but is encouraged, as excellence in teaching is one of the features of NYU Biology. The NYU Center for Advancement of Teaching (CAT) and the NYU Office of Postdoctoral Affairs provide formal instruction in teaching practices. Faculty members who are the primary instructors also provide trainees with constructive feedback on their teaching skills. Instruction and experience in teaching enhances skills required for many careers, including public speaking, organization and time management skills, and communication and leadership skills.

In addition to teaching, trainees have numerous opportunities to engage in mentorship through formal programs including the SURP and K-12 ARISE programs (described above) and through mentorship of junior researchers within NYU Biology laboratories. A central objective of the QBIST program is to enhance preparation for mentoring experiences by providing trainees with relevant training (Objective 2).

2.1.5 Individual Development Plans (IDPs)

A number of faculty members (including QBIST program directors Gresham and Vogel) have implemented annual IDPs for members of their labs. IDPs are based on topics and questions provided in the myIDP section of the American Association for the Advancement of Science (AAAS) website, but are implemented independently by faculty members (see Appendix A for IDP framework). In general, trainees complete a written IDP and meet with their mentor to discuss their responses. IDPs are an effective way of discussing career objectives (Vincent et al. 2015); however, we have not yet rigorously assessed their utility.

2.2 Career outcomes for graduates of NYU Biology PhD program

We have analyzed career trajectories among NYU Biology PhD program graduates over the past 15 years. To quantify career outcomes, we constructed a database of all PhD trainees enrolled in our program between 2000 and 2018 (n=200). We obtained information about trainees’ immediate position following graduation and their current positions. We acquired information for 90 individuals who graduated between 2000-2018. More than 50% of NYU Biology PhD graduates pursued postdoctoral training subsequent to obtaining their PhDs (Figure 4A). Of those who pursued non-academic career paths, 15% obtained employment in non-academic research and 20% pursued opportunities in non-research careers in the biomedical enterprise such as publishing and policy.

We further analyzed these data and found that 42% of the 64 PhD graduates who had pursued postdoctoral training have remained in this position. Of the 37 alumni who have completed their postdoctoral training, 20 (54%) are currently in tenure-track faculty positions and 7 (19%) are in research roles in industry (Figure 4B). These results are consistent with overall trends recently reported in Science (McDowell 2016) and reiterates the critical need for addressing career development training of our trainees for a variety of careers. The complete PhD graduate data for the last 5 years is presented in Table 8A. Of the 31 students who graduated in the past 5 years, 55% pursued postdoctoral training, similar to the results from the last 15 years.

A complete database of trainee career outcomes will be maintained as part of the QBIST program and the results made publically available through the QBIST web portal. In addition, the QBIST program will implement
several new measures to enhance the tracking of long-term training outcomes as described below (see 9. Program Evaluation).

![Figure 4](image)

**Figure 4. A)** Trainee positions immediately following graduation from the NYU Biology program in the last 15 years (n=90) and **B** following completions of postdoctoral training (n = 37).

### 2.3 QBIST program activities to enhance trainee career development

Building on NYU Biology’s existing strengths and activities to facilitate career development, the QBIST program will expand and enhance career development in several ways:

#### 2.3.1. Enhancing the provision of information on diverse career outcomes among graduates

**QBIST program web portal (http://wp.nyu.edu/qbist).** The QBIST program web portal will provide 1) comprehensive statistics of career outcomes of the QBIST program trainees and 2) career development resources provided through the QBIST program and NYU. The QBIST web portal will include all information on the goals of the QBIST program, its components and key training elements. To contribute to the broader national effort to track the career paths of biology PhD graduates and facilitate contribution of our data to national studies, we will adhere to the recently proposed standardized taxonomy for describing career trajectories of biomedical PhDs (Pickett and Tilghman 2017).

**The “Science Lives” monthly discussion forum.** We will expand a newly introduced informal discussion series in which students, postdoctoral fellows, and faculty meet in an informal setting to exchange information on the variety of career paths available in the biomedical sciences. The program was inspired by the “Growing up in Science” series developed by Professor Wei Ji Ma and Professor Cristina Alberini in the NYU Center for Neural Science (Ma 2017), which provides students and postdoctoral researchers with the opportunity to learn about career paths - inside and outside of academia - including changes in direction, rejections, and other challenges. This program has been very successful in broadening students’ career perspectives (Ma 2017).

We ran a pilot of the seminar series in Spring 2018 and are expanding it for the coming academic year. At each meeting, the speaker(s) will provide a 20-minute summary of their career path followed by a question/answer session led by a moderator. The moderator is a graduate student who acts as a host for the speaker, which provides students with an additional opportunity to practice leadership and public speaking. The goal of these sessions is to provide insights into the variety of career options available to NYU Biology PhD program graduates and to demystify the process of career development through frank and informal discussions with academic and nonacademic professionals at different career levels. In addition, speakers are encouraged to comment on skills that they obtained in graduate school that have proven critical for success in their professional environments, such as leadership, time and project management, and the ability to prioritize and familiarize oneself with a new topic.
2.3.2. Facilitate personalized mentoring and support in career development

**Individual Development Plans (IDPs).** QBIST program mentors will use annual IDPs for all QBIST program trainees to facilitate personalized career planning and mentoring. QBIST program trainees will complete written IDPs and meet annually with their mentors to discuss their contents. Guidelines for meaningful discussion of IDPs (Vincent et al. 2015) will be provided to mentors and mentees; and, mentors will be provided with advice and guidance by the QBIST program directors, Gresham and Vogel, who have already implemented annual IDPs in their own laboratories (example IDPs are provided in the Appendix A). The value of IDPs will be evaluated as part of the QBIST program survey (see Evaluation and Assessment Instruments in Appendix C).

**Mentoring QBIST program trainees from underrepresented groups.** The QBIST program will ensure that additional mentoring is provided for trainees from underrepresented groups. All QBIST program trainees who identify as members of underrepresented groups will have the option to receive additional mentoring from a faculty mentor of their choice as outlined in the Trainee Retention Plan. This mentor will meet with the QBIST program trainee every 4 months. The mentor will ensure the trainee has access to relevant resources and will help identify any issues that affect the trainee’s experience in the QBIST program. The mentor will also function as an advocate for the trainee’s needs as required and solve any upcoming issues.

2.3.3 Formalize training in mentoring and leadership skills

**Training in mentorship.** The development of mentoring and leadership skills is one of the objectives of the QBIST program (Objective 2). QBIST program trainees will receive training as mentors with special emphasis on mentoring students from underrepresented backgrounds through formal instruction in the QBIST workshop as described in the Overall Training Plan (QBIST Program Activity 4).

2.3.4 Provide opportunities for QBIST program trainees to gain meaningful experience in non-traditional biomedical career paths

**Internship Program.** Facilitated exploration of biomedical careers outside of the traditional academic track is one of the objectives of the QBIST program (Objective 3). To enhance career development we will introduce a formal internship program as described in the Overall Training Plan (QBIST Program Activity 4). Participation in this program will provide trainees with experiential learning in non-academic career paths available to PhD scientists in the biomedical workforce.

3. Program Oversight, Program Faculty Selection, and Mentor Training

We have developed a robust approach to overseeing the various aspects of the QBIST program including all activities and progress towards objectives, selection of program faculty and training of mentors. The **QBIST program executive committee** will be responsible for managing administration of the program. In addition, we will establish a **QBIST program advisory committee** to provide objective feedback on the effectiveness of QBIST program activities.

3.1 QBIST program executive committee

To oversee the program and to ensure its successful execution, we have established an executive committee. The QBIST program executive committee will be responsible for managerial aspects of the program as well as selection of trainees to be admitted to the QBIST program. The committee will also be responsible for assessing QBIST program mentors and identifying potential additions to the QBIST program faculty. The QBIST executive committee is composed of:

- David Gresham (Associate Professor, QBIST program director)
- Christine Vogel (Associate Professor, QBIST program director)
- Justin Blau (Professor), Chair of NYU Biology who has overall responsibility for the teaching, mentoring, and research activities in the Department. He also led the NYU Biology PhD program for several years as Director of Graduate Studies and thus is well acquainted with all aspects of the existing PhD program.
● **Edo Kussell** (Associate Professor) is the Director of Graduate Studies at NYU Biology. In addition to his expertise in overseeing the NYU Biology PhD trainees, he has expertise in biophysical modeling of evolution and gene expression.

● **Christine Rushlow** (Professor, QBIST program mentor) has worked as the Director of the M.S. Program for several years. Under her stewardship, the Masters program has recently expanded training in computational and quantitative biology. She is a leading expert in developmental systems.

● **Richard Bonneau** (Professor, QBIST program mentor) is the Director of the Center for Data Science and is jointly appointed in the Center for Data Science, Courant Institute of Mathematical Sciences, and Flatiron Institute. He is an expert in machine learning and date science, quantitative modeling of transcription regulatory networks and computational prediction of protein folding.

The QBIST Program Executive Committee will ensure that the program’s objectives are fulfilled by meeting annually to discuss progress. Moreover, the committee will ensure that QBIST program activities are aligned with the larger NYU Biology PhD program and that successful innovations in the QBIST program are broadly adopted to enable the entire PhD program to benefit. At each annual meeting the committee will assess the extent to which the QBIST program is achieving scientific excellence, facilitating and promoting the career development of trainees, and promoting a diverse and inclusive faculty and trainees with respect to experience, gender and underrepresented groups. The QBIST executive committee will address feedback provided by the QBIST advisory committee in their annual written report (see Advisory Committee) and make written recommendations, which will be made publically available on the QBIST web portal, and implemented under the guidance of the QBIST program directors.

### 3.2 QBIST program advisory committee

Objective assessment of the QBIST program will be facilitated by the formation of an advisory committee comprising education, scientific and career development experts. The selection and function of the QBIST program advisory committee are outlined in the Advisory Committee document. Briefly, the QBIST program advisory committee will receive an annual written report from the QBIST program directors summarizing assessment of the program through analysis of the Annual Survey. On the basis of this report, an annual meeting with the QBIST program directors, and discussions with QBIST trainees the advisory committee will provide written recommendations to the QBIST program executive committee.

### 3.3 Faculty selection

Mentors for the QBIST program are all members of NYU Biology. The Department has undergone a major expansion over the last 15 years with the addition of 15 new faculty positions. As a result, the faculty represent a broad diversity of scientific interests and backgrounds. Newly recruited faculty have predominantly developed research programs with strong quantitative components resulting in an increasingly quantitative-focused graduate curriculum, which is one of the primary motivations for this proposal. In addition, the expansion of the faculty has increased the overall diversity of the department with respect to gender and ethnicity.

Faculty will be selected for the QBIST program based on an outstanding record of scientific research that combines large-scale experimentation and systems-level integration and a commitment to mentoring and mentee training. The portfolio of QBIST program mentors is diverse with respect to discipline, gender, ethnicity, and career stage (Figure 1). The QBIST program executive committee will consider the ongoing appropriateness of QBIST program mentors on an annual basis. If a conflict or case of misconduct arises, the Conflict Resolution Protocol (see Appendix E) defines the pertinent procedures. QBIST program mentors who fail to adhere to the expectations of the program will be dismissed from the program.

### 3.4 Mentor training

**Commitment to excellence in teaching.** All QBIST program mentors are committed teachers who teach courses at the undergraduate and graduate levels and have a demonstrated track record of commitment to PhD training. All faculty contribute to common courses taken by PhD trainees including the core seminar courses, in which students read and discuss primary literature with faculty. Importantly, the QBIST program faculty are also primary instructors in courses in quantitative biology that comprise the sequential curriculum detailed in Activity 2 of our proposal: Biostatistics (Gunsalus), Applied Genomics (Gresham), and Machine
Commitment to excellence in mentoring. All QBIST program faculty are committed to excellence in mentoring and have mentored a combined total of 87 PhD trainees corresponding to collective 432 years of PhD trainee mentoring experience (Table 2). QBIST program faculty are committed to ongoing training in mentorship. To that end, on April 18, 2018, we organized a full-day workshop by the National Research Mentoring Network (NRMN) to provide mentor training. The evidence-based training included the following topics: Aligning Expectations; Addressing Equity and Inclusion; Articulating Your Mentoring Philosophy and Plan; Assessing Understanding; Cultivating Ethical Behavior; Culturally Aware Mentoring; Enhancing Work-Life Integration; Fostering Independence; Maintaining Effective Communication; Promoting Mentee Research Self-Efficacy; and Promoting Professional Development.

Seven of the 17 QBIST program mentors attended the entire workshop. Three faculty (Satija, Sanjana, Huang, who are all junior faculty) have recently attended similar courses at Cold Spring Harbor Laboratories. The NRMN workshop will recur every three years and QBIST program faculty will be strongly encouraged to attend. QBIST program faculty will also be encouraged to make use of the NYU Center for the Advancement of Teaching, which offers NYU faculty and graduate students a variety of teaching-focused programs and services, including lectures and workshops. The Center’s event schedule includes training in strategies for effective learning, active learning, writing to learn, critical thinking, and collaborative learning. QBIST program mentors will be asked to attend at least one event per year. This training will provide QBIST program mentors with approaches to mentoring that go beyond the traditional one-mentor-one-student model, such as building a network of multiple mentors who address a variety of skills and competencies.

4. Institutional and Departmental Commitment to the Program

Institutional commitment. At the institutional level, NYU has a long-standing record of strong commitment to PhD training in NYU Biology. NYU supports trainees through annual provision of seven fellowships (the “McCracken fellowships”) to the department, which provide a stipend of $38,000 per year and subsidized housing in Stuyvesant Town at a cost of $12,000/year for each student. Provision of this stipend does not require any teaching commitment, and if trainees elect to work as a teaching assistant they receive additional remuneration. In addition, the NYU Graduate School of Arts and Science (GSAS) further supports PhD trainees by contributing $1,000/student for conference attendance and by sponsoring various academic and social events. NYU is committed to supporting the QBIST program at the institutional level through continued support of the overall PhD training program. Please see Letters of Support from Dean for Science Michael Purugganan (Professor, NYU Biology) and NYU President Andrew Hamilton (Professor, Department of Chemistry).

Departmental commitment. The central mission of NYU Biology is to combine outstanding biomedical research and training. Thus, PhD trainees are a central focus of our activities. The departmental commitment is reflected in the time and resources committed to formal instruction of PhD trainees. Please see Letter of Support from Professor Justin Blau, Chair of NYU Biology.

Through a combination of institutional (i.e. McCracken fellowships) and PI funding, NYU Biology is able to admit and support 11-14 new PhD trainees to the program each year (Table 6A). A cost sharing mechanism provides continuous stipend support for trainees in which the mentor assumes increasing financial responsibility during the five year period. Importantly, all NYU Biology PhD trainees are guaranteed full funding (of $38,000/year) each year during their tenure at NYU, regardless of the funding status of their faculty mentor. This guaranteed twelve-month stipend enables students to focus on their dissertation research and studies without seeking additional employment or compensation.

In addition, NYU Biology provides the following means of financial support: upon entering the program all trainees receive departmental funds to purchase a computer; to support conference attendance the Department provides $1,000 per student per year; the Department sponsors the Annual Graduate Student Retreat, and a PhD trainee-hosted seminar speaker during the academic year. To promote and recognize excellence in research, teaching, and leadership, NYU Biology gives several awards to PhD students on an
annual basis worth a total of $3,100. Additionally, NYU Biology sponsors the entire running costs of the SURP, which includes all travel and living costs for each participant. As of 2017, NYU Biology also supports all PhD trainees between years 2 and 6 with $300/month to mitigate the extreme cost of New York City housing.

5. Training Program Directors

The Directors of the QBIST program are David Gresham (PI) and Christine Vogel (PI), who are both tenured Associate Professors in NYU Biology. Co-directorship of the program is designed to ensure diverse and thoughtful decision-making and to provide complementary scientific, mentoring, and leadership expertise (see Multiple PD/PI Leadership Plan). Vogel and Gresham will assume primary responsibility for administrative duties associated with running the program and serve on a year-around basis. The QBIST program directors will be supported by the the QBIST executive committee and QBIST advisory committee (see Advisory Committee).

David Gresham (QBIST program director, Associate Professor) is an expert in adaptive evolution and post-transcriptional gene expression regulation. His lab has discovered novel mechanisms of gene regulatory evolution and regulated changes in mRNA degradation. He has developed methods for global analyses of RNA dynamics, large-scale pooled genetic screens, and methods for quantifying DNA copy number changes in single cells during adaptive evolution. The Gresham lab is committed to publishing reproducible research by making all data and computer code publically available. Gresham’s leadership experience is reflected in his role as the Faculty Director for Bioinformatics at NYU Biology. In this capacity, he oversees a team of computational biologists who provide research support for next generation sequence analysis. Gresham is committed to PhD training having mentored 8 PhD students and to enhancing diversity through continued participation in the SACNAS conference and the NYU Biology SURP.

Christine Vogel (QBIST program director, Associate Professor) is an expert in proteomics and bioinformatics. She runs a lab integrating diverse, quantitative data types describing multiple levels of gene expression regulation using mass spectrometry and high throughput sequencing-based methods (RNAseq, ribosome profiling, protein occupancy). Her lab discovered novel roles for protein ubiquitination and has developed integrative methods for analysis of time series expression data. Vogel has a demonstrated record for training biomedical scientists: in her 7 years as a PI she has mentored 5 PhD students and developed and taught graduate-level courses in systems biology. Vogel has a long-standing commitment to enhancing diversity and has been a mentor in the SURP and K-12 ARISE programs, and a presenter in the World Science Festival, and the Girls in STEM Outreach programs for the past 4 years. She received extensive mentoring, leadership, and teacher training during a 3-day workshop in “Leadership in Biosciences” at the Cold Spring Harbor Laboratory and the 8-week online course “Teaching Science in Higher Education”. Vogel also leads the Proteomics Facility at NYU Biology.

Gresham and Vogel organized an 8-hour faculty mentoring workshop run by the NRMN in April, 2018, which provided instruction on effective mentoring strategies for trainees, with a particular focus on mentoring trainees from underrepresented groups. In addition, Vogel, in conjunction with Dr. Christine Ponder (Director, Office of Postdoctoral Affairs) has developed and tested modules for the QBIST workshop on training in mentoring.

6. Preceptors/Mentors (Program Faculty)

Diversity of NYU Biology faculty. Of the 38 research faculty in NYU Biology, 24% are female. All female faculty are part of the CAS Women Faculty group headed by Professor Carol Reiss who is PI of the NIH BEST-funded NYU STEP/program. The CAS Women Faculty group offers various events for mentoring and career development of female faculty. Of the 38 NYU Biology faculty, 5 do not identify as being of European ancestry. Three of the faculty at NYU Biology self-identify as members of the LGBTQ community.

Diversity of QBIST program mentors. Program faculty for the QBIST program comprise 17 faculty from NYU Biology whose primary research focuses on integrative and quantitative approaches to biological systems. The QBIST program faculty comprises 8 female faculty (47%) who span all career stages from Assistant Professor (Huang), to Associate Professor (Ercan, Gunsalus, Vogel) and Professor (Coruzzi, Carlton, Ghedin, Rushlow). Gender equality among our program faculty is of particular importance given the fact that over 50% of our
trainees are female scientists. The 17 program faculty provide equal representation of all career stages (5 assistant professors, 5 associate professors and 7 full professors). Eight of the 17 faculty are from countries outside of the US, which include 2 faculty from Latin America (Mazzoni, Carmona-Fontaine). Two QBIST program faculty identify as LGBTQ. QBIST program faculty actively promote diversity within the department. Professor Carlos Carmona-Fontaine has led the founding of a SACNAS chapter at NYU to support Hispanic students and faculty. Professor Mark Siegal has participated in panels such as the Out Panel with LGBTQ+ Faculty as part of the PRISM series organized by Rockefeller University. Thus, the QBIST program faculty are diverse with respect to gender, ethnicity, background, and career stages.

Commitment to excellence in research. The QBIST program faculty are united by a common interest in quantitative approaches to biological systems using a variety of approaches and model systems (Figure 1). Research encompasses a wide range of research areas including ecology and evolution, microbiology, developmental biology, genomics, and systems biology. Two program faculty focus on infectious disease (Ghedin, Carlton), 5 program faculty focus on cell and developmental biology (Rushlow, Christiaen, Gunsalus, Ercan, Mazzoni), 3 program faculty focus on cancer biology and non-genetic cellular heterogeneity (Carmona-Fontaine, Sanjana, Siegal), and 7 program faculty study gene expression regulation in a variety of organisms (Coruzzi, Birnbaum, Huang, Bonneau, Vogel, Gresham, Satija).

The 17 QBIST faculty maintain highly productive laboratories; all faculty are funded by external sources (Table 4) with the exception of Professor Carol Huang, who started in her independent position on January 2018 and is currently supported by start up funds. Professors Satija and Sanjana are both funded through the NIH New Innovator awards (funding is administered through their affiliation with the New York Genome Center). Although the research focuses of the 17 QBIST program faculty represent a diversity of topics, they are unified by their generation of large-scale data sets, integration of diverse data types, and the application of quantitative methods and machine learning to biological problems. Thus, the proposed quantitative curriculum (QBIST program activity 2) will directly complement the research in participating faculty laboratories and trainee dissertation research.

QBIST program faculty have a long history of close interaction and collaboration as reflected by the frequency of co-mentorship of trainees (Figure 1). Current and previous trainees are co-mentored by Q Bonneau/Ghedin, Bonneau/Vogel, Christiaen/Vogel, Bonneau/Christiaen, and Gresham/Siegal. QBIST program faculty also broaden the scope of interactions available to trainees through their affiliations, which include the NY Genome Center (Satija & Sanjana), the Center for Data Science (Bonneau), the Flatiron Institute (Bonneau), NYU Abu Dhabi (Gunsalus), and the NYU Medical School and NYU School of Public Health (Ghedin, Carlton).

7. Trainee Positions, Recruitment, and Retention

Selection of NYU Biology PhD trainees

We apply a holistic approach to assessing applicants to the NYU Biology PhD program. Applicants are selected based on their application materials, which comprise a personal statement on research interests, a CV, letters of recommendation, transcripts, and grades. A key selection criterion is a demonstrated interest in research. Typically, this is reflected in prior research experience either as an undergraduate researcher or employment as a laboratory technician. Indeed, trainees who enrolled in our program in the last five years have an average of 23.9 months of research experience prior to commencing their PhD training (Table 6A). A demonstrated aptitude for research is assessed through letters of recommendation. Our application process disregards quantitative metrics of prior academic success as we have found that standardized assessments, including the GRE, have no correlation with student outcomes. Selection of potentially suitable applicants is undertaken by the entire department using a two-step process of independent review followed by a department-wide meeting.

We invite all suitable applicants (typically ~60 individuals) to visit the department for a two day visit. The purpose of the visit is to provide potential trainees with a comprehensive orientation of NYU Biology and the PhD program. A key feature of the visit is the opportunity for potential trainees to interact with current trainees both formally, through a poster session, and informally through a dinner and social gathering. In addition, during the visit each applicant has five 30-minute interviews with different faculty members. The purpose of the interview is to enable both faculty and applicant assessment of the extent to which the applicant is an
appropriate match for the research and training interests of the department. A key feature of our PhD application process is that all faculty participate in the visit and interviews. To accommodate the applicants’ schedules, we hold two separate visits each of which comprises two days of activities. Following applicant visits and interviews, all faculty contribute to the assessment and identification of ~30 applicants to whom we make offers.

Recruitment, selection and retention of QBIST program trainees from diverse backgrounds

We will admit 4 students annually to the QBIST program, each of whom will be supported for two years. Analysis of the past 5 years of the NYU Biology PhD program indicates that we admit 5-9 (mean = 6.8) eligible trainees per year (Table 6A). The QBIST program will be the only NIGMS-funded training grant in NYU Biology. As the QBIST program will operate in years 2-3, trainees will be selected from the cohort of eligible students (Table 1) following successful completion of the first year of the NYU Biology program. To broaden the impacts of the proposed activities we will make the newly introduced QBIST program activities available to all NYU Biology PhD trainees on a voluntary basis. Moreover, support of the QBIST program by NIGMS will allow us to grow the NYU Biology PhD program through the support of an equivalent number of slots (8) through a combination of institutional and departmental funds (see attached Letters of Support from Professor Justin Blau, Chair of NYU Biology and Dean for Science, Professor Michael Purugganan).

To increase diversity of PhD trainees, we will expand several measures as outlined in the Recruitment Plan to Enhance Diversity. These efforts include faculty attendance at the annual ABRCMS and SACNAS conferences and recruiting students from SURP. We will also ensure that trainees are informed and have ready access to existing resources, as outlined in the Trainee Retention Plan. These resources include the NYU Center for Multicultural Education and Programs (CMEPS), the NYU LGBTQ Student Center, the Office of Global Spiritual Life, the Henry and Lucy Moses Center for Students with Disabilities, and the NYU Graduate Women in Science (GWINS) association.

8. Training Outcomes

To assess the effectiveness of the existing NYU Biology PhD program, we have compiled complete information on all PhD graduates over the past 15 years. Tables 5A, 6A and 8A contain information for the past 5 years, but the results presented here cover both the past 5-year and 15-year period. This analysis shows that NYU Biology has had much success in PhD training outcomes and reveals quantitative improvements over the last 5 years (2013-2018) compared with the preceding 10 years (2003-2013) as detailed below.

Research accomplishments of recent graduates. PhD trainees who successfully completed their graduate training in the past 5 years (n = 51) published a total of 70 first author papers and 163 total papers corresponding to a median of one first author papers and three co-authored papers per student. In the preceding 10 years, PhD trainees published a median of 1 first author papers and co-authored a median of 2 papers. Thus, the typical research output of our PhD trainees has steadily increased. Several students at NYU Biology have received competitive predoctoral fellowships from external funding agencies including the National Science Foundation and Boehringer Ingelheim Fonds. In the past 5 years, PhD trainees have been awarded 15 internal awards (e.g. the NYU Dean’s Dissertation award) that provide university support for the last year of the PhD program.

Rate of PhD degree attainment and time-to-degree. The time to degree attainment has decreased in the past 5 years compared to the preceding 10 years (p<0.05). In the past 5 years, the median time to degree attainment has been 6 years whereas it was 6.5 years in the preceding 10 years. Outliers in the past 5 years reflect unique scenarios, in which trainees were provided with additional time to address personal issues. Importantly, these cases have entailed the full financial support of the department.

Recruitment and success of underrepresented groups. The number of PhD trainees from underrepresented groups has significantly increased in the last 5 years (Table 6A). Students identified as belonging to underrepresented groups take the same time to degree completion as other students (Wilcoxon test, p>0.05) and publish a similar number of papers (Wilcoxon, p>0.05).

Career outcomes of recent graduates. Of those students who graduated in the past 5 years, over 50% have pursued postdoctoral training. A majority of those who elected to not pursue postdoctoral training obtained
employment in the pharmaceutical industry. Analysis of graduates over the past 15 years indicates that 20 are now in tenure-track academic positions.

Our analysis shows that the NYU Biology PhD program has a strong record of accomplishment and demonstrates systematic improvements in metrics of trainee success. The QBIST program will build on this upward trajectory with a view to further enhancing research productivity, time to degree, diversity, and career preparation.

9. Program Evaluation

Quantitative Evaluation of QBIST Program Objectives. We will work with Professor Susan Kirch, a science education expert in the Steinhardt School of Education at NYU and affiliated faculty in NYU Biology, to evaluate the effectiveness of the QBIST program. An essential means to quantify the extent to which the program’s three objectives are met by the proposed activities will be the “QBIST program survey” (see Evaluation and assessment instruments). The survey is designed to evaluate:

1. The impact on student learning outcomes with respect to skills and knowledge
2. The effect on research productivity
3. The impact of leadership and mentoring experience in the SURP and K-12 ARISE programs
4. The impact on the acquisition and application of transferable skills
5. The role of the internship program in defining trainee career paths
6. The impact of the QBIST program on perceptions of diversity

The QBIST program directors will assume primary responsibility for administering and analyzing the survey results. The survey will form the basis of quantifying the effectiveness of the QBIST program in meeting our objectives. The quantitative assessment will be performed annually and summarized in the annual report to the QBIST program advisory committee.

Plans for responding to internal and external outcomes analyses. Objective evaluation of the QBIST program will be facilitated by consultation and reporting to the QBIST advisory committee and QBIST executive committee. The advisory committee will receive the results of the evaluation in the form of a written report annually, which will be prepared by the QBIST program directors. Based on the report, the advisory committee will meet with the QBIST program directors to discuss proposed changes and additional areas of concern. The QBIST advisory committee will convey written recommendations to the QBIST program executive committee, who will collectively devise a plan for implementing any recommended changes.

Mechanism for long-term tracking trainee and career outcomes. Although QBIST program trainees will be in the program for only a 2-year period, we aim to test the impact of the program beyond this time, in particular with respect to i) training outcomes during the subsequent years of the PhD training and ii) career outcomes. To this end, our survey (see Appendix C) will be completed every year by all QBIST trainees before (year 1) and after (years 4-6) participation in the QBIST program.

We have established a database of all PhD graduates from the NYU Biology PhD program over the past 15 years. We will maintain this database with the aim of keeping track of trainee career outcomes. To facilitate continued contact with PhD graduates we will:

1. Maintain our internal database of graduate career outcomes through direct communication with alumni and coordination with the NYU STEP program, which has established a career outcome database from all NYU PhD graduates.
2. Establish an annual alumni newsletter that will be disseminated to all alumni providing updated information on graduate program and departmental activities.
3. Invite all program alumni to the annual Systems Biology Symposium, Developmental Genetics Symposium, Darwin Day lecture and Departmental Retreat.
4. Maintain a LinkedIn page dedicated to NYU Biology PhD alumni.

Dissemination of program results. We will make all analyses of the QBIST program publically available on the QBIST web portal. Information will include: 1) application data; 2) analysis of QBIST objectives; 3) research outcomes and time to degree; and 4) career data as obtained from survey results and admissions information. These data will be presented in graphical form with links to raw data to facilitate broader meta-analyses of graduate programs.
10. Proposal Summary

We have designed a Quantitative Biological Systems Training program that builds on the strengths of the existing NYU Biology PhD program and adds crucial new components that prepare trainees for a wide variety of biomedical careers. Through the adoption of four key new activities we will ensure that PhD training results in the acquisition of robust and broadly applicable skills in data science applied to biomedical research, the development of mentorship, leadership and professional skills and the opportunity to gain meaningful experience in the variety of career opportunities available to the highly skilled trainees that graduate from our program. The new activities we will introduce are designed to meet the three primary objectives of the QBIST program thereby fulfilling our central mission. Success of these activities will benefit the entire NYU Biology PhD program. Ultimately, the QBIST program will benefit the entire biomedical research enterprise through a commitment to outstanding research and training and the adoption, assessment and dissemination of new training activities that will inform to the national effort to enhance PhD training for the betterment of society.


