



University of Colorado **Boulder**

2019 Program Review

BioFrontiers Institute

Academic Review and Planning  
Advisory Committee Report

Approved

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## Process Overview

The Academic Review and Planning Advisory Committee (ARPAC) review of the BioFrontiers Institute was conducted in accordance with the 2019 program review guidelines. Self-study responses were prepared by the unit and checked by an internal review committee composed of two University of Colorado Boulder (CU Boulder) faculty members outside of the unit. The internal reviewers submitted a summary of findings derived from the unit's self-study report and from interviews and/or surveys with faculty and staff members and student unit members. An external review committee, consisting of two experts from outside of CU Boulder, visited the unit and submitted a report based upon review of relevant documents and interviews with faculty and staff members institute students and university administrators. Internal and external reviewer comments and recommendations are shared when relevant throughout this report.

# Academic Review and Planning Advisory Committee (ARPAC)

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## Unit Overview

The Office of Data Analytics (ODA) maintains a standardized description of the BioFrontiers Institute [on its website](#). ODA updates the profile annually in the fall semester. This report cites data posted in October 2018, reflecting the state of the BioFrontiers Institute as of the academic year (AY) 2017-2018.

## Disciplinary context

The BioFrontiers Institute devotes its energies to advancing human health and welfare through interdisciplinary research and education at the forefront of the biological sciences. Currently, 18 faculty members representing eight College of Arts and Sciences (A&S) departments and two College of Engineering and Applied Science (CEAS) departments lead this work as the institute's core researchers. Core faculty members benefit from training in two fields (biology and another field such as one of the physical sciences: computer science, mathematics, or engineering) and acquire access to facilities, resources, and colleagues that enhance innovative research and enable its practical application. Several faculty members have joint appointments with CU's Anschutz Medical Campus, illustrating what the self-study calls a "close and special relationship" between BioFrontiers and Anschutz. The institute's design for interdisciplinarity allows it to tackle problems beyond the reach of scientists working independently. BioFrontiers affiliates achieve cross-cutting research between biology and computer science, mathematics, or engineering. The institute offers its researchers the resources and collegial contacts that facilitate new engagements and pave the way for the work of turning discoveries into practical applications. The institute is well positioned to navigate the conjunction of bioscience and the business of bioscience, a conjunction that aligns BioFrontiers' interests with the biotech industry's in an orbit that regularly spins off business startups. The external reviewers describe BioFrontiers as a "bold vision for interdisciplinary biosciences" and commend it as "a highly successful experiment" in hiring and training truly

interdisciplinary scientists. The existence of similar institutes or programs at peer universities remains unclear in the self-study report.

#### Research and scholarship

BioFrontiers prides itself on research that takes an interdisciplinary approach, emphasizing collaboration among scientists possessing diverse expertise. The institute eschews a single goal to focus instead on a variety of “interdisciplinary research themes” that evolve as discoveries advance. BioFrontiers currently pursues four interdisciplinary themes: biology computation, biology physics, bioengineering, and therapeutic intervention. The institute depends on its high-performance computing, gene sequencing, and advanced microscopy facilities to accomplish this work. Available not only to the BioFrontiers research community but also to targeted collaborators, these core facilities encourage collaborative research and enable cost-sharing.

BioFrontiers’ 18 core faculty members achieve persistent success. In the years since the institute’s inception in 2011, BioFrontiers’ core faculty members have published upwards of 829 times in a wide range of distinguished venues (Science, Cell, Nature, Proceedings of the National Academy of Sciences, etc.). Grant funding is similarly abundant, with 40 active and 62 completed grants from sources such as the National Institutes of Health, the National Science Foundation, the Howard Hughes Medical Institute, and the Bill and Melinda Gates Foundation, among others. Core faculty members have received numerous international, national, and local awards and honors (45 and counting), among these a Nobel Prize, a National Medal of Science, an American Heart Association Distinguished Faculty Award, six NSF CAREER Awards, and awards from the Alfred P. Sloan and the Boettcher foundations, as well as appointments to the American Academy of Arts and Sciences and several other national academies. Examples of

BioFrontiers' high-impact research include the study of double-stranded ribonucleic acid (RNA) as "a non-invasive biomarker of infection" (funded by the Defense Threat Reduction Agency) and the development of a new form of biostasis that eliminates the need to cool tissue in order to preserve it (funded by Defense Advanced Research Projects Agency). BioFrontiers' research lives up to its name.

#### Collaborations

As mentioned above, the collaborations at the heart of BioFrontiers' work increasingly promote the practical application (and capitalization) of research. In the words of the self-study report, "the Institute has become a leader in the translation of research into real-world outcomes," advancing Colorado's leadership in bioengineering and the potential this work holds for health and healing. At the time of its self-study, BioFrontiers had counted over 90 formal and informal engagements with industry, ranging from mutually conducted research to consultations on innovative projects. These associations have yielded 592 patents, 267 inventions, and 20 new companies (a count including results produced by BioFrontiers' predecessor, the Colorado Initiative for Molecular Biology). To foster synergy among education, research, and enterprise, BioFrontiers hopes to co-locate industry collaborators within its academic laboratories – a program it tentatively calls "ibid" (Latin for "in the same place"). Six companies (among these, Double Helix Optics and Arpeggio Biosciences) currently benefit from these arrangements. Collaboration also gives purpose to BioFrontiers' local partnerships: with the National Institute of Standards and Technology, for instance, or the Anschutz Medical Campus. For BioFrontiers, such collaboration is foundational to training and sustaining a new generation of interdisciplinary scientists.

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| National<br>and<br>international<br>context | BioFrontiers provides global leadership in interdisciplinary teaching, research, and innovation in the biological sciences. In lieu of belaboring the institute's renown, it's sufficient to note the external reviewers' opinion that it "has been a resounding success that is unique in the national and international landscape."                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Campus<br>context                           | Established in 2003 as the Colorado Initiative in Molecular Biology (CIMB), the unit attained university institute status in 2011. CIMB's director had previously pursued interdisciplinary biomedical research at the Howard Hughes Medical Institute (HHMI), serving for nine years as HHMI's president. Initially housed in dispersed facilities, the institute in 2012 acquired a permanent and consolidated home in the newly constructed Jennie Smoly Caruthers Biotechnology Building (JSCBB) located on CU Boulder's East Campus. From its start, BioFrontiers was devoted to training, placing, and sustaining interdisciplinary faculty entrepreneurs in biomedical research. Given this mission, BioFrontiers offers no undergraduate training but focuses instead on offering an innovative PhD certificate program, IQ Biology, that recruits students from a wide variety of science backgrounds. Since its founding in 2011, IQ Biology has admitted sixty students and graduated seventeen, placing every graduate into faculty, postdoctoral, or industry positions. The external reviewers highly commend this "wonderful and rare experiment" in interdisciplinary education and urges "ongoing support from administration to fully realize the vision and make it sustainable." |
| Faculty<br>and<br>research<br>personnel     | According to the ODA AY 2018-2019 BioFrontiers data profile, the institute employs 48 research personnel (one research faculty member, 19 research associates, 20 research assistants, and eight postdoctoral associates and fellows). In addition to these, two tenured faculty members are rostered in the institute (the executive director and an associate director).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

Other BioFrontiers core faculty members remain rostered in affiliated departments. The total number of core faculty members has grown from 11 in 2011 (from four departments in A&S and CEAS) to 18 (from ten different departments, eight in A&S and two in CEAS). BioFrontiers aspires to have a total of 25 core faculty members. Although the institute claims affiliation with 10 departments, the great majority of core faculty members today (18) belong to three (Biochemistry, MCDB, and Computer Science).

In 2016, BioFrontiers pursued a multiple faculty line “cluster hire” devoted to computational biology as a shared interdisciplinary research theme. BioFrontiers is currently pursuing another cluster hire, this time in regenerative biology and engineering. The external reviewers note that the recently recruited cadre of junior faculty members “comprises an outstanding group by all national and international standards.” The turn to cluster hiring anticipates the external reviewers’ suggestion that BioFrontiers confront the prospect of pursuing “mission-specific themes.” BioFrontiers offers its junior affiliated faculty extensive mentoring tailored to the unique needs of interdisciplinary teachers, researchers, and entrepreneurs. The institute supplements mentoring in home departments with individual and collective meetings designed to assist new professors in all aspects of their developing careers. Faculty mentoring in BioFrontiers provides a model that other CU institutes might emulate. In 2016, BioFrontiers began appointing research professors to renewable three-year terms with research and service split 90% to 10%. Teaching responsibilities aside, the research faculty members contribute as the institute’s other faculty members do, participating in policy discussions, faculty recruitment, program development, and mentoring. Finally, the external reviewers emphasize the importance of smooth leadership succession when the current executive director steps down in 2020, urging an internal

appointment as the “best way to build on [BioFrontiers’] current success.”

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| Staff                   | According to the ODA AY 2018-2019 BioFrontiers profile, the institute’s staff personnel consisted of 18 exempt professionals, six student research assistants, and 13 student hourly employees. Staff members provide extensive administrative support to core faculty members and the IQ Biology PhD certificate program. In 2018, following a formal evaluation that led to staff promotions, reassignments, and a succession plan to address the impending retirement of the operations and finance director, BioFrontiers reorganized its staff.                                                                                                                                                                                                                                                      |
| Undergraduate education | While core faculty members teach undergraduates in their home departments, BioFrontiers plays no direct role in undergraduate education. The self-study mentions the possibility, arising out of the Computational Biology cluster hire, of “creating a curriculum” (certificate, minor, or major) that could serve A&S and CEAS undergraduates as well as graduate students “in need of quantitative training.” The role Biofrontiers would play in this curriculum remains unclear.                                                                                                                                                                                                                                                                                                                     |
| Graduate education      | As indicated above, BioFrontiers’ teaching contribution comes through its IQ Biology PhD certificate program, devoted to interdisciplinary bioscientist training. The program’s teaching and mentorship roles are not restricted to BioFrontiers’ core faculty members alone but remain open to interdisciplinary science, technology, engineering, and mathematics (STEM) faculty members across CU Boulder and the Anschutz Medical Campus. A three million-dollar NSF Integrative Graduate Education and Research Traineeship (IGERT) grant got the certificate rolling. IQ Biology has proved successful in training recruits to become, in the words of the self-study report, “entrepreneurs, data scientists, and interdisciplinary researchers in industry and academia.” Admitted students (from |

a pool that in 2019 included over 200 Ivy league and top state school applicants) receive training that crosses conventional disciplinary boundaries. The certificate's course of study opens with Bootcamp, an intensive peer-led program held during the week before fall semester that introduces students to quantitative biology and its related skills. In their first year, IQ Biology students explore general educational opportunities that include cross-departmental curricula and lab rotations, team science projects, collaborative outreach opportunities, and professional development programs. The program encourages students to explore a variety of STEM disciplines. In year two, they choose a dissertation advisor and a PhD program from one of ten affiliated departments, enabling sharper focus on a particular theme. The external reviewers stress the importance of "strong navigational assistance" during this transition. Students receive advising from faculty members in different departments, and many choose to join a department they didn't initially consider. An academic advising committee meets with each student individually to discuss coursework, lab rotations, professional development, etc. The BioFrontiers interdisciplinary education director meets individually with all students once a semester. Coursework often follows a "3+1" model that combines a three-credit course with a one-credit practicum emphasizing, in the words of the self-study, "hands-on technical skills and research-based teamwork." Other educational opportunities include the Idea Exchange (a weekly seminar focused on faculty member research, networking, and professional development), the IQ Biology Symposium (a program for bringing academic and industry speakers to CU), and interdisciplinary talks sponsored by the BioFrontiers Biotech Opportunity Seminar and the Qualitative Exploration and Discussion Supergroup.

Until the completion of the initial IGERT grant in spring 2018, all IQ Biology certificate program students received full funding for

their first two years. Starting in fall 2018, second-year funding was reduced to a \$10K fellowship. IQ Biology faces the challenge of redressing this funding loss, which clearly compromises the financial security of some students, especially those not awarded teaching or research assistantships that come with tuition remission. The self-study report suggests that for CU Boulder “to remain competitive [in this area], university-level funding” will be “required for interdisciplinary graduate education.” The external reviewers recommend securing 20–24 “endowed studentships” to sustain the excellence of IQ Biology’s interdisciplinary education.

BioFrontiers’ graduate students tend, not surprisingly, to pursue interdisciplinary research, often enabled by a seed grant, that combines mathematical, computational, biological, and engineering principles to advance health and healing and create entrepreneurial opportunities. New applications of analytical and computational techniques to biological problems, for instance, yield innovative treatments for chronic wounds and invasive cancers. The promise of such research finds fulfillment in the 100% placement of all IQ Biology certificate program graduates either in university jobs (73%) or with industry (27%), sometimes with companies started at CU. BioFrontiers graduates enjoy, for example, faculty appointments at the University of Minnesota and the University of Wyoming, postdoctoral positions at Oxford University, the University of Pittsburgh School of Medicine, and the Max Planck Institute of Complex Systems, and industry jobs at companies such as Arpeggio Biosciences (founded by an alumnus) and Tuple Health. By measure of placement, BioFrontiers’ commitment to interdisciplinary education pays off handsomely, both for the institute and for the scientists it trains.

Given the cross-departmental character of the IQ Biology certificate program, the Office of Data Analytics offers no

graduate student demographic information. The BioFrontiers self-study notes that women in IQ Biology represent 39% of its past and current students, a strong showing compared to the 25% average in U.S. quantitative PhD fields (math, computer science, and engineering). The self-study categorizes 12% of the total as “international” students and says that only 7% identify as belonging to “underrepresented minority groups in STEM.” The report acknowledges the paucity of the latter and pledges to address it, but without proposing specific steps beyond waiving graduate application fees, strengthening partnerships with the Office of Diversity, Equity, and Community Engagement, and recruiting students at “diverse conferences” such as that associated with the Society for Advancement of Chicanos/Hispanics and Native Americans in Science. BioFrontiers supports the work of CU Café, a group organized by science, technology, engineering, and mathematics graduate students that sponsors a seminar series that brings scientists to Boulder who identify as belonging to an underrepresented minority population to talk about their research and field experience.

Graduate student climate in BioFrontiers appears positive, but can be hard to assess because of the great variety of departmental affiliations. Overall satisfaction runs high, over 90% according to a recent survey run by the internal review committee (January 2019). Previously, in 2018, fifty BioFrontiers students participated in a climate survey conducted by ARPAC staff. That assessment (which yielded a 47% student response rate) found that 95.5% “agreed” or “strongly agreed” that they felt treated with respect by faculty and staff members and by peers. A large majority “agreed” or “strongly agreed” that climate felt positive for all gender orientations and students of color. The survey found 23% of respondents to be concerned about humiliation and intimidation. The 2019 internal reviewer survey uncovered majority dissatisfaction (68%) with core

courses, a circumstance noted in the unit's reply to the internal reviewers and addressed in the final version of the self-study, which details curriculum changes meant to remedy the problem. BioFrontiers faces the challenge of a diminishing sense among its students of an IQ Biology program professional identity. First-year students acquire a strong sense of interdisciplinary identity and community that fades as they disperse in their second year to affiliated departments. The task here is to sustain identification with interdisciplinary research beyond the first training year. BioFrontiers has begun to respond to the need, exploring the possibility of a one-credit "high-impact seminar" that would extend interdisciplinary training and innovation into the second year of the certificate program.

#### Postdoctoral training

BioFrontiers' core faculty members have trained approximately 45 postdoctoral researchers since 2011, and the self-study notes that BioFrontiers' core faculty members currently advise 41 more. Most of those 41 are employed elsewhere, since the 2018-2019 the Office of Data Analytics unit profile indicates that BioFrontiers employs only five postdoctoral researchers and three postdoctoral fellows. The self-study report leaves their exact role unspecified beyond repeated mention of postdocs in relation to graduate students. Presumably they enjoy similar interdisciplinary training, access to facilities, and professional opportunities, but greater specificity would illuminate these matters.

#### Budget

The BioFrontiers budget pertains only to institute-controlled funds. Research budgets of core faculty members remain under the control of individual PIs from affiliated departments. The institute budget sustains research, graduate education, and general operations. Based on FY 2018 expenditures, it reached \$3.7 million, apportioned as follows: 26% to administrative personnel, 37% to core facilities, 1% to equipment and space,

8% to research support and start-up costs, 22% to IQ Biology, and 6% to operations and events. Funding derives from a range of sources including federal and non-federal sponsors, state agencies, indirect cost recovery, and philanthropy. Indirect cost recovery for FY 2018 totaled \$368,021 arising from core faculty awards of nearly \$1.3 million, a portion of which gets returned to faculty members to cover research expenses. The self-study states that philanthropy provides significant additional support (although amounts are unstated) and will remain an important funding source for facilities, equipment, and education. Since 2015 the BioFrontiers Advancement Team has helped raise \$6.4 million to create two endowed fellowships for IQ Biology students and to defray construction costs and other expenses. In FY 2018 BioFrontiers PIs received \$7,784,523 for continuing and new research from federal and non-federal sources, including the National Institutes of Health, the National Science Foundation, the Department of Defense, the Boettcher Foundation, the Gates Foundation, and the Searle Scholars Program. The institute generates revenue from internal and external clients using its “cores” of information technology (high-performance computing), next generation sequencing (cutting-edge gene sequencing), and advanced light microscopy (state of the art microscopes) facilities; these also receive supplemental institutional funding. Underscoring the importance of the three cores to BioFrontiers’ mission, and the institute’s capacity to stay competitive and its interdisciplinary curriculum to remain cutting-edge, the external reviewers mention “specific needs for more resources and attention for these cores.” The end of IGERT support for IQ Biology threatens to vitiate the curriculum, as recent federal funding applications have not borne fruit.

Space  
and  
infrastructure

The BioFrontiers Institute occupies 39,934 square feet (employed as 73% lab space, 25% office, and 2% miscellaneous) in the Jennie Smoly Caruthers Biotechnology

Building (JSCBB) on CU Boulder’s East Campus. Dedicated in 2012, JSCBB received a LEED platinum rating from the US Green Building Council for its many eco-friendly features. A new addition, the E-Wing, opened in 2018, creating additional space for faculty member labs and offices and for industry partner co-locations. BioFrontiers appears unusually happy with its space, putting it, in the words of the self-study, to “excellent use.” The institute re-evaluates infrastructural needs every three to five years and anticipates assigning some space in the E-Wing to future faculty members.

#### Support needs

As stated above, urgent needs include investment in core facilities infrastructure and funding for students in the IQ Biology PhD certificate program.

#### Governance

Alone among CU Boulder institutes, BioFrontiers reports directly to the provost. Its bylaws originate with those approved for CIMB in 2010. Updated in 2016 and again in 2018, the bylaws establish an institute operational structure that provides flexibility as different aspects of BioFrontiers’ mission evolve. Current bylaws conform to campus norms with regard to governance structure, voting, and faculty member hiring procedures. Because BioFrontiers does not roster faculty, the bylaws forgo both merit review and promotion and tenure standards and procedures. They contain no grievance procedures but state that the executive director “will maintain a written policy for the handling of grievance involving Institute personnel.”

Leadership of the BioFrontiers Institute includes an executive director, a chief scientific officer, two associate directors, and program directors for education, research, operations and communications, and strategic partnerships. Governance operates by means of an executive committee (three faculty members appointed by the executive director), the BioFrontiers

Institute Council (18 core faculty members plus 19 faculty representatives from affiliated departments), the BioFrontiers Institute Advisory Board (18 members from academia, government, industry, and the local community), and the IQ Biology Advisory Board (nine members from academic institutions, research foundations, and U.S. health organizations). These bodies provide counsel and direction that shape and sustain the three-pillar institute mission: research, education, and impact.

#### Inclusive excellence

Regarding inclusive excellence, the BioFrontiers self-study report feels long on aspiration and short on substantive facts. ODA cannot offer a clear diversity profile because it records BioFrontiers as rostering only two tenure-stream faculty members, the executive director and one associate director. On the basis of visual cues, admittedly dubious, provided by photos in the self-study report, it appears that the 18 core faculty members divide evenly between men and women. Ethnic and racial identification is much harder to determine, and the self-study report offers little guidance beyond a general impression that faculty members in STEM sciences from underrepresented minority populations remain few and far between. The graduate student population, according to the self-study report (cited above), identifies 39% as women and 7% as people of color, the latter percentage predictably low. The many laudable suggestions in the self-study report about how to attract and support more graduate students from underrepresented minority populations remain largely aspirational. The institute bylaws lack a diversity statement. The three pillars of the BioFrontiers mission—research, education, and impact—make no obvious room for diversity as a constitutive value. Inclusiveness around race and ethnicity, for all its apparent urgency, remains more an amorphous ideal for BioFrontiers than a reality.

## Climate and culture

Climate surveys conducted by ARPAC staff in March 2018 and addressed to BioFrontiers' faculty and staff members and graduate student appointees can be read as painting a generally sunny picture of its life and culture. The 13 core faculty members who participated in the survey reported overwhelmingly positive perceptions in regard to respect and positive climate for all classes of people. Where they couldn't express an opinion in response to survey statements, they replied "no opinion," as, for instance, regarding climate for people of different political or religious views. All respondents felt they were valued members of BioFrontiers and reported a positive sense of community.

Results were similar among graduate student appointees: A total of 44 (47%) graduate students responded to the survey, and all "agreed" or "strongly agreed" that they were treated with respect. As with faculty members, when queried about climate for particular groups, the graduate students (with only a few exceptions) expressed "no opinion" rather than disagreement. Over 20% of graduate students, however, indicated that some faculty members behave in humiliating or intimidating ways. A large majority found faculty members friendly and supportive, and most felt valued as members of the BioFrontiers community. Staff responses (at a 65% participation rate) were much the same, although generally higher regarding climate for particular groups and a little lower concerning humiliation and intimidation. About 20% of staff members indicated that they didn't feel like valued members of the unit. All groups tended to defer to having no opinion about climate quality for members of minority groups – at a surprisingly high rate—33-55%, for instance, regarding people of color.

The self-study concludes that "BioFrontiers, as judged by the survey, appears to have a very positive relationship with a

broad range of students, faculty, and staff from many departments.” Internal and external reviewers generally concur. When the internal reviewers raised questions about graduate student satisfaction with core courses, the institute responded quickly with a proposal for change. The institute response to the internal reviewers also suggested changes in climate survey pools and protocols that might yield results better applicable to the BioFrontiers community, students especially.

## Past Reviews

The current ARPAC review is the BioFrontiers Institute's first.

## Analysis

Strategic  
vision  
and  
planning

Strategic planning at the BioFrontiers Institute proceeds with impressive energy, and its plans appear vivid and concrete.

BioFrontiers asserts its identity as a center for interdisciplinary research and education with confidence, envisioning four growth areas:

1. “Lead in biomedical research.” Over the next seven years, BioFrontiers plans to expand “beyond the walls” of the institute to pursue research with a “synergistic effect” on the broader community. The institute will seek funding for collaborative projects involving faculty members from CU Boulder and the Anschutz Medical Campus. It envisions offering an IQ Biology certificate track for students from “traditional departmental PhD programs.” And it plans to host speakers in seminars sponsored by other departments to build more connections with them.
2. “Advance impact on human health through interaction with industry.” BioFrontiers hopes to solidify relations it has already developed with many industrial collaborators. This aim involves enhancing the co-location of businesses in JSCBB’s E-Wing of (the so-called “ibid” initiative). BioFrontiers also intends to leverage campus resources to enhance the connection between research and entrepreneurship by building on relationships with the Leeds School of Business and CU’s Research and Innovation Office.
3. “Shape tomorrow’s leaders.” BioFrontiers intends to expand its interdisciplinary educational mission by increasing its annual incoming IQ Biology class size from its current 6–10 students to 10–14. To do so, it will seek seed funding not only from CU’s provost and deans but also from federal, foundation, and philanthropic sources that support interdisciplinary research and teaching. While its

advancement team recently secured funding for two endowed student fellowships, BioFrontiers realizes keenly that charitable donations alone cannot sustain the IQ Biology PhD certificate program. Expanding class size would require hiring an additional staff member to help support IQ Biology.

4. “Sustain robust innovation.” BioFrontiers remains committed to innovation leadership. The institute intends to continue producing cutting-edge biomedical research that further enhances its global reputation, and attracts leading scholars to CU Boulder. This aim will involve sustaining the superiority of its core facilities in scientific computing, advanced imaging, and DNA sequencing. The institute will also pursue Anschutz Medical Campus collaborators, including the possibility of a bridge professor appointment to enhance links between the campuses. A final target in this focus area involves raising philanthropic funding for collaborative research projects with multiple PIs. The great majority of external funding currently accrues to individuals. Given BioFrontiers’ commitment to collaboration, it makes good sense to seek increased funding for truly collaborative research projects.

While commending the energy and specificity of this strategic plan, ARPAC suggests that BioFrontiers also anticipate the ways it might evolve in several key areas. First, the internal reviewers mention perceived inequities in funding levels of among the three focus areas. It would be helpful to encounter a clear description of the way such decisions should be made to assure equity in the midst of an interdisciplinary focus. Second, the self-study report indicates that BioFrontiers aspires to increase its core faculty members to as many as 25 members. ARPAC would like to see a long-term hiring plan that indicates how BioFrontiers intends to reach this goal and the role further cluster hiring might play in the process. Finally, as noted below,

a BioFrontiers' commitment to interdisciplinary training and research complicates the pursuit of specific research themes, which affects fundraising as well as long-term student identification with interdisciplinarity. ARPAC urges BioFrontiers to address this tension and its possible resolution(s) directly.

#### Leadership and institute structure

The institute's pending leadership transition presents an opportunity to reflect on its future. Both the self-study report and the external reviewers endorse an internal search for a replacement. With the appointment of a new executive director, ARPAC encourages BioFrontiers to examine the advantages and disadvantages of more closely aligning its structure and reporting procedures with those of other CU Boulder institutes, especially as doing so might further enhance the institute's collaborative ties, especially with those other research institutes.

#### Undergraduate education

While BioFrontiers does not offer undergraduate degree programs, the self-study report occasionally mentions undergraduate participation in labs, workshops, and competitions as well as possibilities to enhance undergraduate interdisciplinary education. ARPAC encourages BioFrontiers to reflect more specifically on the ways it might advance undergraduate education at CU, including prospects, if any, for a more direct role in interdisciplinary training, which could include sponsoring an undergraduate certificate program similar in aims to the IQ Biology PhD certificate program.

#### Graduate education

All stages of assessment in this review process—the self-study report, and the internal and external reviews—identify clear challenges facing the IQ Biology PhD certificate program. Chief among them is funding, which BioFrontiers says it will seek from institutional, federal, foundational, and philanthropic sources. But the institute advances little in the way of a concrete plan for doing so. The external reviewers suggest that

the institute secure philanthropic funding for 20–24 endowed graduate students rather than just two. Given the importance and high praise the external reviewers bestow on the IQ Biology program’s interdisciplinary training, such a plan would seem imperative.

Several challenges also haunt the IQ Biology certificate curriculum’s aims and outcomes. BioFrontiers has already begun addressing student concerns about the usefulness of core courses and has begun to organize more opportunities for interaction during students’ second through sixth years of study. The external reviewers report that a concern “raised by several faculty and students was a desire for a more concrete theme or set of themes, beyond simply being interdisciplinary.” The internal reviewers similarly note that “some faculty and students questioned whether IQ Biology was providing truly interdisciplinary training, since there was “a perception of two internal cohorts or ‘tracks’ (one computational and one biological),” describing too the apparent difficulty of crossing between the tracks. The self-study report doesn’t respond directly to this concern, which might be reinforced by the imbalance of participation among the ten affiliated departments (core faculty members coming mostly from three). Further complicating matters is the internal reviewers’ sense that “the majority of the faculty who were present at our meetings did not appear to be deeply engaged with the IQBio program.”

This added concern raises an issue that surfaces several times over the internal and external reviews: the long-term value of BioFrontiers’ commitment to general interdisciplinarity. Does interdisciplinary training in fact produce a new breed of collaborative researcher? The usual metrics of job placement, publication, and funding may not measure such success clearly or completely. The institute’s recent turn to cluster hiring (in computational biology in 2016 and currently in regenerative

biology and engineering) suggests a turn also to more specialized research themes. Is a new relationship emerging in BioFrontiers between general interdisciplinarity and such specialization? Does the perception of dual educational tracks—computational and biological—confirm or contradict interdisciplinarity? While interdisciplinary education and research remain at the heart of BioFrontiers’ mission, the self-study acknowledges that student investment in that ideal fades after the first year. Open discussion might be in order about the future of interdisciplinarity and its relationship to specialization, especially in regard to job placement. Do graduates aspire to interdisciplinary careers in education, research, or industry? Do they realize those aspirations? ARPAC wonders whether BioFrontiers might track the interdisciplinarity of their graduates’ job placements and ensuing careers. Assessing the outcomes of interdisciplinary training, might also have implications for fundraising.

#### Postdoctoral training

The self-study frequently mentions the participation of postdoctoral fellows and associates in the life of the BioFrontiers Institute (the employment, for instance, of 45 since 2011), but never specifies the training they receive or roles they play. ARPAC would find a clear description of postdoctoral training informative, even if training occurs largely in the labs of faculty members rostered in affiliated departments.

#### Budget

BioFrontiers urgently needs funding for increasing graduate student support and sustaining core facilities. Regarding the latter, the external reviewers contend that the institute's information technology, next generation sequencing, and advanced light microscopy facilities "are critical to sustaining and strengthening ties across campus as well as maintaining scientific excellence in BioFrontiers. They are also an excellent recruiting tool." Although the institute generates revenue from these facilities, they fall short of being self-sustaining and

require supplemental institutional funding. The amount is left unstated in the self-study, however. ARPAC suggests that the institute indicate exactly how much money it requires.

Fundraising, whether for education, facilities, or other projects, is an important aspect of BioFrontiers' operations. The external reviewers indicate that "the fundraising model and priorities going forward need to be articulated more clearly to faculty" and suggest that in this regard "having at least one topic 'theme' to discuss could be helpful." The balance between interdisciplinarity and specialization again appears to be a crucial issue. Fundraising devoted to specific themes might address a range of concerns at play in the various reviews of BioFrontiers. The external reviewers note further that "the absence of a specific scientific focus created challenges for fundraising, student and faculty member recruiting, and successful development of large multi-investigator 'center grants'." Targeted appeals to funders who have designated receptivity to supporting faculty members or graduate students in a particular area and targeted appeals to faculty members who want to collaborate with those similarly skilled might enhance external funding success and faculty member recruiting. An additional benefit of targeting a single theme could be the reduction of dissatisfaction among faculty and staff members, and students in different areas, who believe they are receiving relatively fewer resources and/or less respect from administrators. The internal reviewers state that "there was a perception among staff, students, and faculty that the staffing levels were imbalanced."

Space,  
infrastructure,  
and  
support needs

For the moment, BioFrontiers enjoys space equal to its ambitions. It envisions enhancing co-location of industry partners in the E-Wing of the Jennie Smoly Caruthers Biotechnology Building in coming years.

|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Governance           | Grievance procedures for faculty and staff members and for students do not appear in BioFrontiers' bylaws. The bylaws would also benefit from including a diversity statement.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Inclusive excellence | As noted above, BioFrontiers' commitment to diversity, while sincere, remains largely aspirational in all areas other than hiring women, itself a commendable achievement. No mention appears in its mission statement of a commitment to inclusive excellence. No explicit diversity statement appears among materials provided for this review. While the institute supports initiatives such as CU Café and other seminars that showcase research by scientists from underrepresented minority populations, the profile of its own student body (7% identifying as people of color) qualifies the force of such commitments. Revealingly perhaps, this issue goes unnoticed by the internal and external reviewers. Conventional explanations would reference the scarcity of minority candidates for admission to programs like the IQ Biology PhD certificate. ARPAC suggests BioFrontiers take explicit steps to address this problem and become a leader in producing diverse as well as interdisciplinary researchers. ARPAC also feels strongly that CU Boulder should provide institutional support toward this goal. It's worth noting in passing that BioFrontiers' various governing and advisory bodies (the BioFrontiers Institute Council, the BioFrontiers Advisory Board, and the IQ Biology Advisory Board) remain apparently overwhelmingly white, and with the exception of the first, largely male. How will BioFrontiers address this admittedly historical and structural imbalance? |
| Climate and culture  | Climate and culture in the BioFrontiers Institute seem generally positive. Where possible problems exist, as with student concerns about core courses or staffing imbalances between core facilities, BioFrontiers addresses them promptly. Surveys indicate relatively low concern about humiliation and intimidation and relatively high feelings of respect and inclusion.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

One curious result, however, is the tendency for a high percentage of respondents to claim to have no opinion in regard to the quality of the institute's climate for minority groups, particularly people of color. Is climate for minorities really so opaque? Surveys communicate the impression that diversity concerns remain unaddressed and contribute little to the institute's culture.

## Recommendations

The members of the Academic Review and Planning Advisory Committee address the following recommendations to the BioFrontiers Institute and to the offices of responsible administrators:

- To the Unit:
1. Create a strategic plan that includes detailed descriptions of the following: the process used to determine allocation of resources among institute priorities; the money necessary to sustain the excellence of core facilities; a strategy for raising funds to support the IQ Biology PhD certificate program; and the means proposed for increasing the numbers of graduate students (10-14 per year) and core faculty members (up to 25 total).
  2. Discuss administrative structure and reporting procedures. Consider the advantages and disadvantages of structurally aligning administration and reporting with other CU institutes. Include analysis of different possibilities.
  3. Examine the appropriate balance for BioFrontiers between interdisciplinarity and specialization as new leadership directs the institute into its next seven years and adjudicates the role each will play in future education, research, and hiring.
  4. Produce a plan for fundraising grounded in clear description of the emerging relationship between interdisciplinarity and specialization. Indicate possible funding sources.
  5. Develop and implement a concrete plan to improve diversity at all levels that aligns with CU's inclusive excellence standards and institutional commitments. Include specific actions to address the scarcity of minority participation in BioFrontiers at both student and leadership levels. Craft a publicly available diversity statement.

6. Create a sustainable funding model for core facilities that maintains their cutting-edge status. Be explicit about current shortfalls and needs. Advocate for a funding commitment from the provost.
7. Create a sustainable funding model for IQ Biology students that includes applications for specific grants and strategies for securing more endowed funding for students. Advocate for a funding commitment from the provost.
8. Continue to address the tendencies among students in the IQ Biology PhD certificate program to assume that different educational tracks exist and to lessen identification with interdisciplinary research after their first year.
9. Assess the long-term effects of interdisciplinary and collaborative research by tracking student outcomes after graduation and placement in academic or industry careers.
10. Describe the ways undergraduates currently contribute to BioFrontiers' operation and consider the possibility of sponsoring and funding an interdisciplinary undergraduate certificate program combining biology and computer science.
11. Clarify the role postdoctoral fellows and associates play in sustaining BioFrontiers' mission of advancing interdisciplinary teaching, research, and entrepreneurship.
12. Include grievance procedures and a diversity statement in BioFrontiers' bylaws.
13. Fund and support funding efforts for core facilities, IQ Biology, and interdisciplinary research.

To the Dean of the  
College of Arts and  
Sciences:

14. Support cluster hiring directed toward focused themes.

To the Dean of the  
College of Engineering  
and Applied Science:

15. Fund and support funding efforts for core facilities, IQ  
Biology, and interdisciplinary research.

16. Support cluster hiring directed toward focused themes.

To the Provost:

18. Consider BioFrontiers' proposal for a sustainable funding  
model for core facilities and IQ Biology.

19. Consider the most effective administrative structure and  
reporting procedure for BioFrontiers as part of the process  
of preparing for the appointment of a new executive  
director.

## Required Follow-Up

The director of the BioFrontiers Institute shall report annually on the first of April for a period of three years following the year of the receipt of this report (i.e., April 1st of 2022, 2023, and 2024) to the vice chancellor for research and innovation and dean of the institutes, and to the provost on the implementation of these recommendations. Likewise, the vice chancellor for research and innovation shall report annually on the first of May to the provost on the implementation of recommendations addressed to the institute. The provost, as part of the review reforms, has agreed to respond annually to all outstanding matters under their purview arising from this review year. All official responses will be posted online.