



## New Program Report

**Date Submitted:**

11/20/2023

**Institution**

Missouri University of Science & Technology

**Site Information**

**Implementation Date:**

8/1/2024 12:00:00 AM

**Added Site(s):**

**Selected Site(s):**

Missouri University of Science & Technology, 206 Parker Hall, Rolla, MO, 65409-0470

**CIP Information**

**CIP Code:**

260101

**CIP Description:**

A general program of biology at the introductory, basic level or a program in biology or the biological sciences that is undifferentiated as to title or content. Includes instruction in general biology and programs covering a variety of biological specializations.

**CIP Program Title:**

Biology/Biological Sciences, General

**Institution Program Title:**

Biological Sciences

**Degree Level/Type**

**Degree Level:**

Doctoral Degree (Research PhD)

**Degree Type:**

Doctor of Philosophy (Ph.D.)

**Options Added:**

Collaborative Program:

N

**Mode of Delivery**

Current Mode of Delivery

Classroom

Student Preparation



## New Program Report

Special Admissions Procedure or Student Qualifications required:

The target population for this program will be students who have completed a bachelor's or master's degree in Biological Sciences or a related undergraduate or graduate program. The course of preparative study will be dependent on the student's intended focal area of scholarship and the track (biomedical, bioinnovation, environment) the student chooses to pursue. The student's committee will determine if additional coursework is necessary for the student to succeed in their chosen track.

Specific Population Characteristics to be served:

n/a

### Faculty Characteristics

Special Requirements for Assignment of Teaching for this Degree/Certificate:

Must members of the graduate faculty and hold a Ph.D.

Estimate Percentage of Credit Hours that will be assigned to full time faculty:

100%

Expectations for professional activities, special student contact, teaching/learning innovation:

n/a

### Student Enrollment Projections Year One-Five

<b>Year 1</b>	<b>Full Time: 3</b>	<b>Part Time: 0</b>	
<b>Year 2</b>	<b>Full Time: 6</b>	<b>Part Time: 0</b>	
<b>Year 3</b>	<b>Full Time: 9</b>	<b>Part Time: 0</b>	<b>Number of Graduates:</b> 0
<b>Year 4</b>	<b>Full Time: 12</b>	<b>Part Time: 0</b>	
<b>Year 5</b>	<b>Full Time: 15</b>	<b>Part Time: 0</b>	<b>Number of Graduates:</b> 0

**Percentage Statement:**

n/a

### Program Accreditation

Institutional Plans for Accreditation:

This new biological sciences Ph.D. degree needs no accreditation to function but will be assessed together with other graduate degrees in the biological sciences graduate program via the Higher Learning Commission.

### Program Structure

**Total Credits:**

72

**Residency Requirements:**

n/a

**General Education Total Credits:**

42

**Major Requirements Total Credits:**

72

**Course(s) Added**



## New Program Report

COURSE NUMBER	CREDITS	COURSE TITLE
xxxxx	2	Graduate Journal Discussion
xxxxx	12	Elective Lecture or Optional Non-biology Graduate Certificate Courses
xxxxx	3	Degree Track Required Course
xxxxx	6	Degree Track Elective Courses
xxxxx	2	Graduate Seminar
xxxxx	30	Research
xxxxx	3	Proposal Writing Course

### Free Elective Credits:

8

### Internship or other Capstone Experience:

All students will conduct research and complete a dissertation. An internship (BioSci 6085 Internship) is optional.

### Assurances

I certify that the program is clearly within the institution's CBHE-approved mission. The proposed new program must be consistent with the institutional mission, as well as the principal planning priorities of the public institution, as set forth in the public institution's approved plan or plan update.

I certify that the program will be offered within the proposing institution's main campus or CBHE-approved off-site location.

I certify that the program will not unnecessarily duplicate an existing program of another Missouri institution in accordance with 6 CSR 10-4.010, subsection (9)(C) Submission of Academic Information, Data and New Programs.

I certify that the program will build upon existing programs and faculty expertise.

I certify that the program can be launched with minimal expense and falls within the institution's current operating budget.

I certify that the institution has conducted research on the feasibility of the proposal and it is likely the program will be successful. Institutions' decision to implement a program shall be based upon demand and/or need for the program in terms of meeting present and future needs of the locale, state, and nation based upon societal needs, and/or student needs.

### Contact Information

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## Executive Summary

Missouri University of Science and Technology proposes a doctoral graduate program (Ph.D.) in Biological Sciences. As the University embarks on a bold new vision to address biomedical, environmental, and life science challenges through the interdisciplinary life science initiative, it is essential that the University expands the size and impact of Biological Sciences programs on the S&T campus.

- A doctoral program in Biological Sciences, along with other new programs, will act synergistically to enhance interdisciplinary collaborations among scientists and engineers across the S&T campus to realize the vision of the life science initiative.
- The growth of Biological Sciences on the S&T campus is essential to achieving University goals in growing research impact and breadth, physical infrastructure, faculty recruitment, external funding, enrollment, and diversity.
- Strong student demand for enhanced opportunities to study in life sciences programs on the S&T campus is indicated by exceptional numbers of applications to the Biological Sciences BS/BA and MS programs (relative to other campus programs). The Biological Sciences represents a growth opportunity for Missouri S&T at both the undergraduate and graduate levels, and data suggests biology degree programs serve a broader audience compared to other STEM degree programs.
- In the past decades, Missouri has emerged as a regional hub for biotechnology innovation and a major contributor to the bioeconomy. There is strong market demand for a talented pool of experts, innovators, and life sciences leaders to drive the biotechnology market.
- There is strong evidence that investments are needed in Missouri to increase the capacity for advanced training of the next generation of biological scientists. As the premiere public STEM campus in the University of Missouri System, Missouri S&T must play a leading role in contributing to this mission. We have received positive feedback and strong support from industry representatives and workforce development leaders in the state for a doctoral program at Missouri S&T.
- The proposed doctoral program in Biological Sciences will include three tracks: Biomedicine, Bioinnovation, and Environmental Biology. These tracks are selected to emphasize both the current strengths and future vision of life sciences research on the Missouri S&T campus. Each track will emphasize core biology, interdisciplinary training, and data analytical competencies. We propose an internship option in our doctoral program that will be vital to allow graduate students to establish industry or agency connections while completing their degree.

# 1. Introduction

The 21<sup>st</sup> Century is the Century of Biology. Biotechnology plays a central role in developing solutions to virtually all global challenges now and into the future, including healthcare, food security, renewable energy, bioinspired materials, and management and protection of our environment, ecological resources, and biodiversity. In the past year, the U.S. Congress has budgeted \$2 billion in new investments in biotechnology and biomanufacturing, and training for the next generation of biotechnologists ([White House briefing room release, September 14, 2022](#)). The bioeconomy was valued at \$400 billion in 2016, with projections to increase by \$30 trillion in the next two decades according to the Federation of American Scientists ([Jeffery 2023](#)). The challenges of the future will be met by a workforce of highly trained scientists and experts who can develop and capitalize on emerging biotechnologies and communicate effectively to educate the public on the values of technology adoption. Big ideas and big challenges require the cooperative efforts of interdisciplinary teams of experts. At the center of interdisciplinary translational research in biotechnology are the foundational biological sciences.

The biological sciences are the foundation for existing and emerging industries that drive economic growth and development in Missouri and across our nation. As the leading public STEM university in Missouri, Missouri S&T serves a central role in technology and workforce development for our state. A market analysis, and ongoing conversations with leading employers in the biotechnology industry in Missouri, indicate that Missouri institutions do not currently have the capacity to meet the demand for highly trained senior scientists and experts in biotechnology fields. In fact, the public universities in Missouri graduate fewer Biology Ph.D.'s than the public universities in every one of our eight bordering states. The Biological Sciences department at Missouri S&T is poised to contribute to satisfying this demand through ongoing investments and the development of this proposed doctoral training program.

Missouri S&T researchers are leaders of cross-disciplinary translational technology-driven research. Our university is [undertaking a transformational reorganization to promote the life sciences](#) and to further develop leading interdisciplinary research to advance human and environmental health. Leadership will require collaborative, cross-disciplinary initiatives that capitalize on all the strengths that our university can bring to bear on these challenges. One of those strengths must be in biological sciences research and workforce development. Growth of the Biological Sciences *programs* at Missouri S&T is an essential aspect of realizing the goal of expanding bioengineering, environmental engineering, and bioscience research and training on the S&T campus, and the Biological Sciences department will not be able to meet this demand without the addition of a Ph.D. program.

We propose a new Ph.D. program in Biological Sciences at Missouri S&T in order to secure a foundation and an expansion of translational biological sciences research at our university, to enhance critically needed partnerships between scientists and engineers, and to provide students with opportunities for advanced training in interdisciplinary life sciences research.

The Ph.D. in Biological Sciences will attract and support cutting-edge science and provide a platform for training future researchers and leaders across Biological Sciences disciplines. Although this Biological Sciences Ph.D. program will serve a distinctly different niche than the recently proposed Missouri S&T Bioengineering Ph.D. program, both programs will function synergistically in promoting an interdisciplinary collaborative environment, including the expansion of related research infrastructure, for both biological scientists and engineers.

The objectives of the proposed Ph.D. program in Biological Sciences are:

- 1) To grow and diversify graduate enrollment at Missouri S&T and within the UM System by offering a new Ph.D. program built on the foundations of basic and translational biological sciences.
- 2) To develop a highly skilled workforce and leadership in translational biological sciences to meet the current and emergent needs of the bio-innovation economy, including industries, government and regulatory agencies, and non-governmental organizations. The promotion of internship opportunities with industry and agency partners outside the university is central to this objective.
- 3) To elevate the volume and impact of Missouri S&T's research enterprise by providing new and expanded opportunities for Biological Sciences faculty and our students to engage in interdisciplinary research leading to new collaborations, innovative ideas, and increased scholarly productivity in life sciences research.
- 4) To build new research and educational collaborations with external partners, including those within the UM System. This includes supporting existing institutional focus areas including precision medicine and environmental science. Opportunities for students to pursue internships with industry and agency partners is part of this proposal.

The proposed Ph.D. program in Biological Sciences will be housed and administered within the Biological Sciences Department at Missouri S&T.

## **2. University Mission & Program Analysis**

### **2.A. Alignment with University Mission & Goals**

#### *Alignment with University Mission & Goals*

The mission of Missouri S&T is to “integrate education, research and application to create and convey knowledge that serves our state and helps solve the world’s great challenges.” Our university’s strength is engaging in transformational research that combines science,

technology, engineering, and mathematics. Missouri S&T has the broadest range of engineering offerings among peer institutions, as well as first-rate research programs in basic sciences, including chemistry, physics, and math. The strength of Missouri S&T's research is the integration of science and technology across diverse disciplines to achieve results that address challenges and solve problems. Biological Sciences is currently the only STEM field at Missouri S&T campus that does not award a Ph.D. degree, and so this limits the ability of the University to address fundamental societal challenges associated with the life sciences and limits the opportunities for interdisciplinary collaborations in areas like biomedical engineering and environmental engineering.

With a forward-looking vision and taking advantage of its existing interdisciplinary strengths, Missouri S&T has embarked on the life sciences initiative which addresses biomedical, environmental, and life science issues at the global scale (Figure 1). The Initiative is composed of three cornerstones: biomedical science, environmental & life science, and humanities & social science. The first two cornerstones align with our intent to establish a Ph.D. degree program in the Department of Biological Sciences. The program contains education and research elements that train our students to make consequential and impactful contributions to humanity.

In the past 25 years, S&T has developed national reputations in biomedical science areas including translational medicine (e.g., targeted drug delivery, traumatic brain injuries), regenerative tissue engineering (e.g., bone and wound regeneration), and biomedical informatics using artificial intelligence and machine learning. Our nascent environmental and life science research in ecological remediation and natural resource sustainability has also gained national visibility (e.g., bioremediation of urban runoff in aquatic systems). The intersection of biomedical science and environmental and life science will continue to produce advances in biodiversity prospecting, sensor technology (e.g., disease diagnosis and treatment, environmental sensing), and environmental health (e.g., aerosol toxicity, waste removal in fragile ecosystems). With a master's degree program and a strong tradition of involving undergraduates in research, the Biological Sciences Department has, for decades, participated in or led most of these successful ventures. A Ph.D. degree in biological sciences is long overdue to realize the full potential the campus can offer in basic and applied biological research and education.



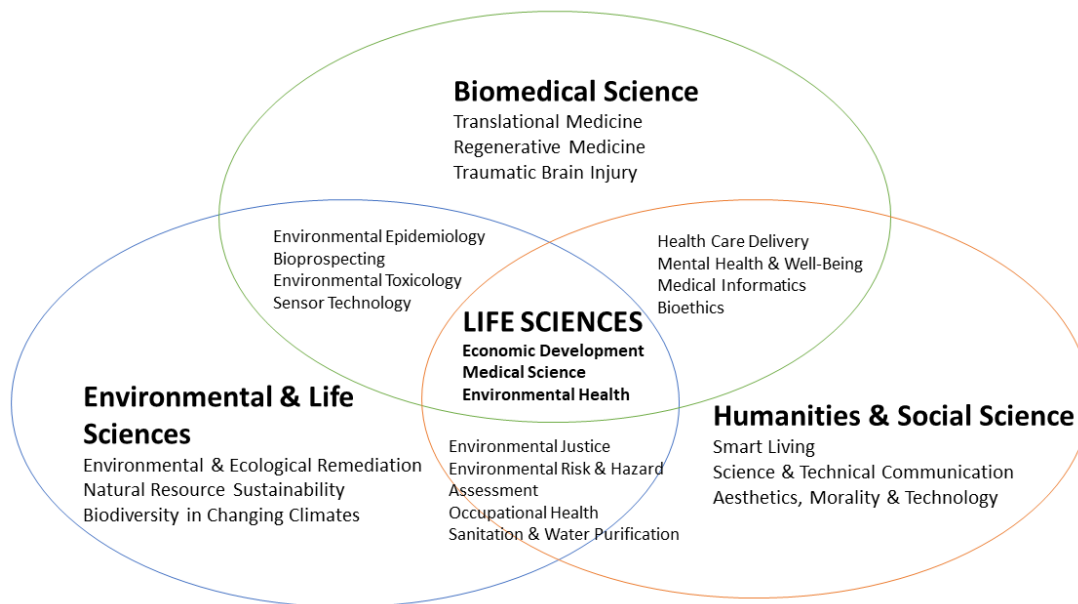


Figure 1: Missouri S&T life sciences initiative.

### *Synergy with Other S&T Programs*

Our university has proposed a new doctoral program in Bioengineering (a separate proposal), administered in the Chemical and Biochemical Engineering Department with this new doctoral program in Biological Sciences (this proposal), administered in the Biological Sciences Department. We envision these two programs producing complementarity and synergy as well as fostering new collaborations. A strong Biological Sciences Department, with a Ph.D. degree program, will form the foundation for expansion of our current emphasis in biomedical applications. Basic science fosters new ideas in translational science. In pursuit of translational medicine, if we do not continue to advance our foundational understanding of human biology, there will no longer be new knowledge to translate.

In the past, S&T investigators in engineering programs such as Chemical and Biochemical Engineering, Materials Science and Engineering, Electrical and Computing Engineering, and Environmental Engineering have formed productive collaborations with faculty in the Biological Sciences Department. Faculty and students in these departments are frequent users of equipment and facilities in Schrenk Hall, maintained and managed by faculty in Biological Sciences, including specialty facilities managed by the interdisciplinary Center for Biomedical Research, and interdisciplinary partnerships and collaborations are numerous.

Successful collaborations between engineers and biologists have produced peer-reviewed publications, patents that have generated significant income for the university, and international recognition. However, on other occasions, these efforts have failed to find sustainable collaboration due to limited capacity in Biological Sciences at S&T. The

consequence is that promising technologies and engineering processes have not been translated to (bio)-medical use. The establishment of collaborations outside our home institution is possible but remains more difficult given the necessary additional investment in time and resources. A critical mass of S&T biologists who can translate basic science will facilitate engagement in exploratory and long-term collaborative projects. An enhanced, better equipped, and larger Biological Sciences Department is the foundation of current and future S&T strengths in applied biomedical and environmental research and education.

Missouri S&T has set an ambitious goal to become an international leader in making consequential impacts in the living world, and our three cornerstones in the life sciences initiative are interconnected via human factors (Fig. 2). Without understanding and accommodating these human factors, effort in advancing biomedical science and environmental and life science become futile. To address these needs, faculty in Psychological Science and in Technical Communications have begun the process to develop new Ph.D. degree programs in their respective areas as well. The involvement of humanities and social science disciplines in the life sciences initiative is in line with the University's goal to elevate the presence of humanities and social science on our campus and beyond, as well as the University's ultimate intent to reach R1 status by FY2030.

#### *Support Infrastructure for Goals*

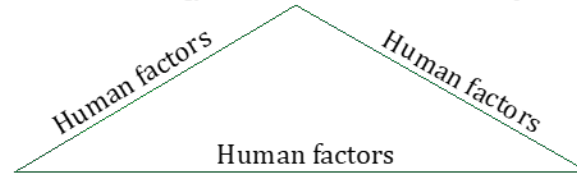
Biomedical science and environmental and life sciences have been, and will continue to be, supported by S&T's immense resources in technologies and engineering processes (Fig. 2). Research in biomedical science will be supported by the Center for Biomedical Research (CBR, leading role), Material Research Center (MRC), High Performance Computing Center (HPCC), Intelligent Systems Center (ISC), and by the Technology Transfer & Economic Development Office. Environmental & life science research will be supported by the Center for Research in Energy and Environment (CREE, leading role), MRC, HPCC, Energetic Materials, Rock Characterization, and Geomechanics Center (EMERGE), Center for Infrastructure Engineering Studies (CIES), and [Center for Intelligent Infrastructure](#) (CII).

#### *Alignment with department goals.*

The Department of Biological Sciences, with our current baccalaureate and MS programs, prepares students for interdisciplinary STEM careers by emphasizing problem solving, innovation, and entrepreneurial thinking. The addition of a Ph.D. program will serve as a catalyst for department growth, expanding research capacity, enhancing existing partnerships with collaborators across disciplines, and attracting sponsored support and investments in personnel and infrastructure. Expansion of research activities will enhance opportunities for our undergraduate students and lead to enrollment growth in both our undergraduate and graduate programs. The addition of a doctoral program is viewed as essential to future department growth.

### Biomedical Science

- CBR: bioanalytical capability
- MRC: biomaterial characterization
- HPCC: AL/machine computing power
- ISC: 3-D bioprinting
- Technology Transfer & Economic Development



### Environmental/life Science

- CREE: environmental chemistry
- HPCC: computing power
- MRC: material characterization
- EMERGe: Geoscience
- CIES/CII: environmental infrastructure

### Humanity / Social Science

- HPCC: computing power on human subject analysis
- CIES/CII: Impact of modern infrastructures on life style changes

Figure 2: Research centers and research infrastructure on the Missouri S&T campus.

## 2.B. Duplication & Collaboration within Campus, Across System

### *Unique features of our proposed program*

Our program will be categorized under CIP code 26.0101- Biology/Biological Sciences, General, and will distinguish itself from similar programs on the other UM System campuses by capitalizing on the strengths and unique research profile of our campus. The Biological Sciences Ph.D. program at Missouri S&T will provide doctoral training opportunities that are not available on the other UM System campuses. Life science faculty members individually offer unique research foci, and doctoral programs are unlike undergraduate and non-thesis masters programs in that doctoral programs do not compete in the same way for enrollment of the same pool of potential students. Students often select programs by reputation, but also by finding scholars and faculty with interests matching their own. Furthermore, doctoral student training is synergistic with and supported by the scholarly pursuits of research faculty. Missouri S&T has a practice of establishing collaborations with companies and national labs that provide opportunities for students to work on-site and gain experience in these interdisciplinary environments. An opportunity for students to conduct internships with these partners is a key feature of this proposal. To maximize the return on scholarly efforts of our biological sciences faculty as well as our institutional investments into faculty and facilities, we need to develop this doctoral program and the students it will bring. The citizens of Missouri will benefit from the advancement of scholarship provided by our faculty and students, as well as the expanded opportunities to pursue advanced training in the scholarly fields uniquely supported by our biological sciences faculty.

Our doctoral program will emphasize interdisciplinary collaboration across the S&T campus, bringing cross-disciplinary technology applications to address fundamental and

translational applications. The integration of technologies and disciplines, and engagement with industry partners, is a strength that is a part of Missouri S&T's reputation. In a nod to our university reputation, Dr. Kristine Callis-Duehl (Dreimeyer Director of Education Research and Outreach, Danforth Center) stated as part of her support for our proposal, *"Missouri S&T is uniquely positioned to connect biological sciences with math, computer science, and engineering to produce researchers who can bring together these fields for true innovation"*, and *"a Ph.D. program that focuses on training students for industry research as opposed to academic research is unique in this area and relatively unique across the country"*. Dr. Christina Taylor (S&T chemistry alum and Computational Molecular Design Lead and Science Fellow, Bayer) compared S&T's strengths to those of her own Ph.D. alma mater, MIT (see her support letter, appendix 3), concluding *"Expanding the Biological Sciences Program to include a Ph.D. will help drive more collaborations between Biological Sciences and many of the areas in which Missouri S&T exhibits strengths"*. Similarly, Dennis Ridenour (President and CEO of BioNexus KC) stated in his support for our proposal *"A new program for doctoral-level training in biological sciences, along with a new doctoral program in bioengineering, will create a dynamic, interdisciplinary collaborative environment to enhance current and future cutting-edge research and advanced training opportunities."*

The foundations for interdisciplinary engagement of biological scientists and our students already occur in existing collaborations with researchers in departments across the S&T campus. In the past ten years, the faculty of our relatively small Biological Sciences department (average 9 tenure-track faculty over the ten-year period) have served in a co-investigator role on 86 interdisciplinary research proposals amounting to \$56 million. The principal investigators of these proposals have come from Chemical and Biochemical Engineering, Civil, Environmental and Architectural Engineering, Electrical and Computer Engineering, Materials Science and Engineering, Mechanical and Aerospace Engineering, among others. In addition, Biological Sciences faculty have served as principal investigators on an additional \$26 million in proposals that included one or more co-investigators from many of the same other departments. Two-thirds of these proposals were submitted to NIH or NSF. There is a high demand across the S&T campus for the expertise provided by Biological Sciences faculty that is essential to many of the ongoing and planned interdisciplinary research programs. The addition of a bioengineering doctoral program and the investments in new faculty that accompany that program will serve to greatly increase the opportunities for Biological Sciences faculty and student collaborators. Adding a doctoral graduate program in our department will maximize the return on investments in our discipline and future collaborations will be strengthened by the enhanced capacity of our department.

Examples of the potential of these collaborations can be seen through the success of our undergraduate students in innovation and entrepreneurship competitions. Interdisciplinary teams of undergraduate students have successfully competed locally and regionally winning several pitch competitions, often against medical students, graduate students, and practicing professionals (see section 3.C.2 for specific examples). Expanding this approach to the proposed graduate program will lead to more opportunities for entrepreneurial successes that benefit the state of Missouri such as patents and start-up companies.

## *Need for foundational science programs on all UM System campuses*

There are four biological sciences departments in the UM System (one on each campus), and currently there are two biological sciences Ph.D. programs, at MU and UMSL. The UMKC campus also has doctoral training in biology, although it employs a different model, with a single interdisciplinary-Ph.D. (iPhD) program that serves all departments on the Kansas City campus

During the preparation of this proposal, we have engaged with department chairs and graduate program directors in biological sciences disciplines on all three of our sister campuses (MU, UMSL and UMKC). These individuals expressed support for our proposal and interest in the potential for enhancement of future collaborations. Dr. Truman (Dean, School of Science and Engineering, UMKC) provided a support letter in which he endorsed our proposal (see letter, appendix 3).

The foundational sciences of any STEM-based curriculum and research focus include biology, physics, chemistry, and math. Missouri S&T, the STEM-focused campus in our system, is the only one of the four campuses that lacks the support and opportunities provided by a doctoral program in biological sciences. This is a key missing component that is essential to the success of the life sciences initiative on our campus.

## **3. Business-Related Criteria & Justification**

### **3.A. Market Analysis**

#### ***3.A.1. Rationale & Workforce Demand for the Program***

##### *Missouri is a Growing Hub of Biomedical, Pharmaceutical and Biotechnology Companies*

In the past ten years, life sciences employment in the U.S. has doubled, representing an annual growth rate of 6.6% compared to the 1.2% annual average for total U.S. employment ([Cushman & Wakefield October 2022 report](#)). According to [Global Market Insight](#), the biotechnology market was valued at around \$497 billion in 2020 and was projected to grow to more than \$950 billion by 2027, at a compound annual growth rate (CAGR) of over 9.4%. Missouri in general, and the St. Louis region in particular, has emerged as a major biotech hub in the Midwest ([St. Louis Bioscience Labor Market Analysis](#)). Outside of St. Louis, much of the biotech industry (broadly speaking) has developed along the I-70 corridor between St. Louis and Kansas City. The top biotech employers in Missouri include large, international companies, like Bayer, Pfizer, Thermo Fisher Scientific, MilliporeSigma, and Eurofins Scientific, to name a few. Top biopharmaceutical companies in Missouri include Mallinckrodt, Genentech, AstraZeneca, GlaxoSmithKline, and Eli Lilly. Institutions like the Donald Danforth Plant Science Center, the Missouri Botanical Garden, and the Stowers Institute are internationally recognized leaders in their fields of life sciences research. In the

past two decades, the St. Louis region has been transformed into a hotbed for bio-innovation. Initiatives to attract, foster and support a vibrant innovation community include [Cortex](#), [T-REX](#), and [BIOSTL](#). St. Louis alone hosts over 1,000 small and startup biotech companies ([BIOSTL](#)). Similarly, [BioNexus KC](#) is a non-profit organization in the Kansas City area advancing life sciences resources, facilitating collaborations, and promoting workforce development.

The major elements that are essential to a successful biotech community are a talented workforce and creative, innovative leaders. At the heart of a region feeding both these elements are world class academic institutions. The leaders and innovators in biotech companies almost universally are subject experts with doctoral degrees. The largest centers of biotech innovation develop around regions with multiple academic research institutions. Missouri is moving in this direction and *with the vision established by the Kummer Institute, Missouri S&T is poised to contribute to growing the influence of Missouri in the biomedical, pharmaceutical and biotechnology industries.*

Public universities should be an important contributor of talent, leadership, and opportunity. There are four universities in Missouri where Ph.D. degrees are awarded in biological sciences. They are concentrated in St. Louis and along the I-70 corridor: Washington University-St Louis, Saint Louis University, University of Missouri-Columbia, and University of Missouri-St. Louis, setting aside UMKC's unique campus-wide interdisciplinary Ph.D. program for which discipline-specific numbers are unavailable. These programs collectively graduated 384 total Ph.D.'s in the five years between 2017 and 2021 for *an average of 77 new scientists with doctoral degrees in biological or life sciences per year in Missouri.*

It is notable that the academic landscape for Biological Sciences Ph.D. degrees in Missouri is dominated by just one university. The Division of Biology and Biomedical Sciences (DBBS) at Washington University graduated 384 PhDs in biological sciences fields in the previous five years (average 77 per year). The DBBS is responsible for almost 80% of biological sciences PhDs awarded in Missouri. The strength of the DBBS is the sheer number and diversity of participating faculty from more than 30 departments across multiple campuses of Washington University in St. Louis. By comparison, the largest public university in Missouri, University of Missouri-Columbia, graduated 53 PhDs from a single department (not including a few more graduates in biomedical disciplines) in the same five-year span (average 10 per year). Saint Louis University and University of Missouri-St. Louis each graduated 26 PhDs from their biology programs in the same time frame (average 5 per year each). Washington University is a highly selective internationally renowned private university, and it is a major driver of the biomedical, biotechnology, and pharmaceutical industries in the St. Louis region. However, as reported in a [Bioscience Labor Market Analysis](#) prepared by BioSTL in reference to graduate programs, "90% of Washington University students are from outside Missouri, 65% are from more than 500 miles away", and "a notable share of these students will not stay in the area after program completion." It is limiting for the region to rely on a single private university that holds such a dominant position for training top leadership talent in the region. Public universities also serve an important role in contributing to the talent pipeline, and while the UM campuses have excellent programs, there is room for more investment and growth. Missouri S&T can

accelerate this development by joining the other three campuses in training leadership talent in the biological sciences for Missouri.

*The Job Market in Missouri for PhDs in Biological Sciences Fields*

In Missouri, the most recently available six-year period 2016-2021 shows 3,617 unique job postings (avg 602 per year) available for job candidates with a doctoral degree in biological sciences. A little over half the jobs for biologists with doctoral degrees were posted by academic institutions (1343 jobs in six years) that hire scientists into permanent faculty and scientist positions, but also many term-limited postdoctoral training positions. Importantly, industries and public agencies also advertised 1,422 positions (avg 237 per year) for scientists with doctoral degrees in biological sciences. In total, within the state, 2.5 times as many non-academic jobs were advertised each year for Ph.D.-level biological scientists as the total number of biological sciences doctorate degrees that were awarded (see previous section). This does not include jobs at academic institutions, which also separately exceeded the number of awarded doctorate degrees by a factor of 2.8. Among the job advertisements reviewed in our market analysis, the non-academic jobs were advertised by biotech companies (474 jobs), biomedical companies (423 jobs), and pharmaceutical companies (178 jobs), as well as government agencies (54 jobs).

Total postings - Ph.D. or Prof degree (all postings):	3617
Summary of top employers (those with ≥10 postings)	
Sum of all academic (universities, research institutes):	1343
Washington University (1,177)	
University of Missouri (50)	
University of Kansas (46)	
Stowers Institute (43)	
Sum of all non-academic (companies, gov agencies):	1422
Bayer (255)	
Pfizer (159)	
Eurofins (49)	
Millipore Sigma (45)	
Mallinckrodt (38)	

Among these job postings, the top job titles (in order of frequency) were medical scientist, biological or life scientist, plant scientist, environmental scientist, food scientist, biochemist, epidemiologist, microbiologist, and wildlife biologist. The top locations for job postings included St. Louis, Kansas City, Chesterfield, Columbia, Jefferson City, and Springfield. Job locations also included over fifty cities and towns throughout the state, including places like Salem, Owensville, Sikeston, Potosi, Ava, Houston and many others (Fig 3).

There is a robust job market for doctoral-trained research scientists in Missouri, and future growth of biotech industries in the region is limited by the availability of a well-trained workforce. Regardless of how the data are parsed, the number of job positions advertised for scientists with doctoral degrees in biological sciences in Missouri exceeds the number of students graduated in Missouri by several times. This places all institutions, both academic and non-academic, in a challenging position to recruit heavily from other parts of the country as well as internationally. It also indicates that the majority of available high-skill, high-paying positions in these industries are filled by non-Missouri residents (or scientists trained outside of our state). This is a fact that was repeatedly emphasized in support letters. Chris Reed (Director of Talent Management, Benson Hill) stated in his support letter *“It is rare that we can identify, engage, and hire a St. Louis based, much less Missouri based, scientist”, and “Missouri would be better served to have more advanced training opportunities in our public universities because those individuals would be more invested or motivated in staying in Missouri, and contributing to the regional economy”*. Dr. Callis-Duehl (Danforth Center) stated *“Industry partners, like the Danforth Center, are importing talent from outside Missouri and often outside of the US to fulfill [biotech] positions.”* Mr. Ridenour (BioNexus KC) stated *“Industry representatives...have cited challenges recruiting necessary talent, frequently resulting in regional companies recruiting nationally or internationally to meet local and regional needs.”* We heard similar sentiments from other industry leaders we contacted. Dr. Taylor stated *“As a hiring manager and Science Fellow at Bayer, I have observed the need to develop and recruit talent in the Midwest firsthand. We have more success with acceptance and retention when we target students that attended a school in the Midwest or have family connections to the Midwest.”* Dr. Borgschulte, Senior Director and Head of Bioprocessing Upstream R&D at MilliporeSigma, stated *“Recruiting top talent for senior scientist-level positions has been a persistent challenge for us at our sites in St. Louis, MO and Lenexa, KS, as we are competing with large biotech and pharmaceutical companies primarily located on the East and West coasts for the same talent pool of candidates. We have found our most successful recruiting efforts often arise from partnerships with regional universities.”*

Another common refrain in our discussions with industry representatives was how important it is for companies to engage with students before they graduate in order to recruit them before they leave the region. In their labor market analysis, BIOSTL reported, in reference to doctoral graduates from current regional universities, “a notable share of these students will not stay in the area after program completion unless local employers connect with them before they graduate.” These same points were emphasized in an article entitled *How mixing academia and industry opens doors in graduate school and beyond* ([Nature, Vol 617, May 2023](#)). This is where we think an emphasis on internship opportunities for our doctoral students will be critical to retaining our graduates in the region after they have graduated from Missouri S&T.



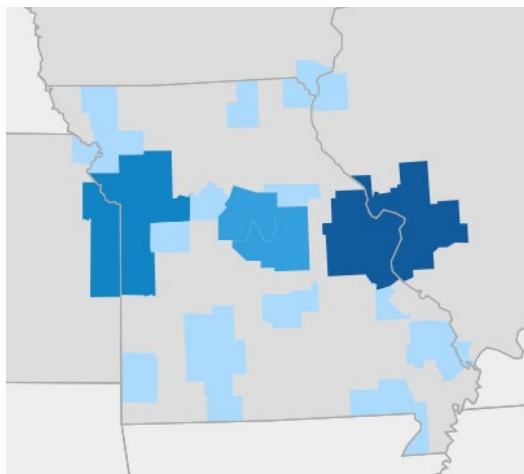


Figure 3: Regional coverage of biological sciences job postings that list a doctoral degree as an educational requirement (darker shades correspond to more job postings).

### ***3.A.2. Student Demand for the Program***

The state of Missouri is currently under-served by the size and capacity of doctoral programs in the biological sciences. In recent years, annual non-academic job postings exceeded annual doctoral degrees awarded by a factor of 2.5. When Missouri under-invests in doctoral training opportunities for our citizens, our students must find programs in other states to meet their educational goals, and our hiring institutions must attract talent from abroad to meet their workforce needs. As noted above, there is evidence that Missouri currently provides *insufficient numbers of doctoral training opportunities* in biological sciences when compared to our bordering Midwestern neighbors. The size of a Ph.D. program, and the number of students it graduates is a direct function of institutional capacity. The number of faculty in a department limits the amount of sponsored research support and the number of Ph.D. students that can be trained. The range of faculty expertise also impacts the range of disciplinary areas that graduate students can pursue. A review of the numbers of Ph.D. graduates from universities with doctoral programs in biological sciences by state can provide some indication of doctoral training capacity. Considering all public and private universities, Missouri ranks in the bottom half among our neighboring states in training capacity to support Ph.D. students in Biological and Biomedical Sciences programs as measured by the *number of Ph.D. graduates per million residents in all programs using CIP code 26 in 2021* (Fig 4a). CIP code 26 includes all programs that focus on biological sciences and the non-clinical biomedical sciences (definition from Department of Education). When considering only *public universities* with Ph.D. programs in biological and biomedical sciences, Missouri ranks last in capacity among our neighboring states by the same metric (Fig 4b).

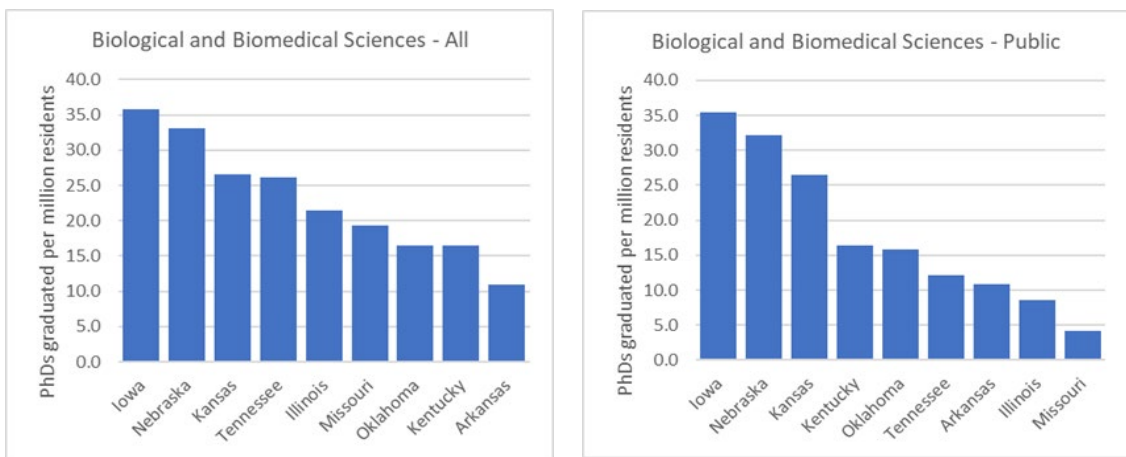


Figure 4: Number of PhDs graduated per million residents in Biological and Biomedical Sciences in 2021 (most recent available data). A) All universities public and private, B) public universities only.

In fact, Missouri capacity at public institutions is currently less than half of the next highest state, Illinois, and only 12% of the per capita capacity of our highest ranked neighbor, Iowa. Importantly, Missouri also ranks last in the number of public institutions that offer Ph.D. program options in Biological or Biomedical Sciences (CIP code 26) on a per capita basis. These numbers clearly show that, on a per capita basis, Missouri has less *capacity* in our public universities than any of our neighbors to train doctoral students in biological sciences. This is not a statement about the *quality* of existing Ph.D. graduate programs at Missouri institutions, including UMC and UMSL, relative to neighboring states. In order for the state of Missouri, and Missouri citizens, to participate in the bioeconomy, and attract businesses engaged in the biotechnology research, we must increase and diversify our capacity to train the next generation of experts and leaders in biotechnology fields. We cannot find ourselves dependent on programs outside our state to provide training to our citizens and import expertise to support our bioeconomy. A doctoral program in Biological Sciences at Missouri S&T will help address this capacity shortage.

### *Enrollment Projections*

Projections of enrollment numbers in a new biological sciences Ph.D. program are based on a variety of factors. First and foremost, Missouri S&T is making bold investments in life sciences research in programs across our campus, with an emphasis on growing our life sciences and engineering programs. These investments include renovations to existing buildings, planning for new research buildings, equipment and specialized facilities, new faculty lines in Biological Sciences, and new bio-related engineering programs (e.g., Biomedical Engineering). These investments are targeted to expand research capacity, and to elevate visibility and competitiveness of our undergraduate and graduate programs in life sciences fields, including Biological Sciences. We have received approval to search in AY23-24 for a new Kummer Endowed Department Chair in Biological Sciences. This individual will be an accomplished scholar and will provide enhanced leadership in the department. We expect to add two additional new faculty to Biological Sciences in the next five years to

support expansion of our own undergraduate and graduate programs, as well as the hiring of new faculty in related fields to support the creation and expansion of other bio-related engineering programs on campus.

We anticipate that this increased visibility of life sciences will double the size of our own undergraduate program, possibly in the next five years, and that student credit hours (SCH) generated by students from other programs enrolling in our courses will more than double as well. Our expectation for overall enrollment growth is based on observations that undergraduate applications to the biological sciences program is currently the fourth highest on our campus behind only Aerospace Engineering, Mechanical Engineering and Computer Science, but our yield rate of new students from these applications is only half of the overall campus average (Fig. 5). Historically, the Biological Sciences program has not been a target for bold investments, rendering it less competitive than other programs on the Missouri S&T campus. That is changing quickly. The investments on our campus under the life sciences initiative in faculty hires, facilities enhancements, and new programs will elevate our yield rate to the campus average and make our undergraduate program one of the largest on our campus.

All of these investments are critical to our plan to support a vibrant doctoral program. The recruitment of top doctoral students requires excellent research programs and facilities, as well as graduate assistantship and fellowship support. Our capacity to attract and support doctoral students will depend on our ability to financially support them. A mature doctoral program should have capacity to provide graduate assistantships and fellowships from a variety of sources, with approximately two-thirds of student support coming from graduate teaching assistantships, and one-third coming from other sources. Graduate teaching assistantships, currently awarded to MS students, are used to support instruction primarily in lab courses. We propose that doctoral students can also be used to support teaching in expanded academic capacities that will include tutoring and grading, recitation sessions for large lecture classes, management of seminars and seminar courses, and lecturers in some introductory and non-majors lecture classes. These expanded uses of doctoral students as Graduate Teaching Assistants will also serve a critical role in reducing teaching effort for faculty members who will require a shift in their workload effort in order to tackle expanded sponsored research program aspirations. At present, our lab course enrollments support eight MS graduate teaching assistantships per semester (fall and spring only). These current MS assistantships will be redeployed to support our PhD students. With enrollment growth and the support of the Dean and the Provost, total assistantship support will be increased to fifteen assistantships per semester in five years. At the same time, we will count on new sponsored research, fellowships (e.g., Kummer Fellowships), and other sources (e.g., new faculty startup packages) to generate additional graduate student support. This means that during the first five years, we anticipate providing twelve months of support for all doctoral students through various sources of funding.

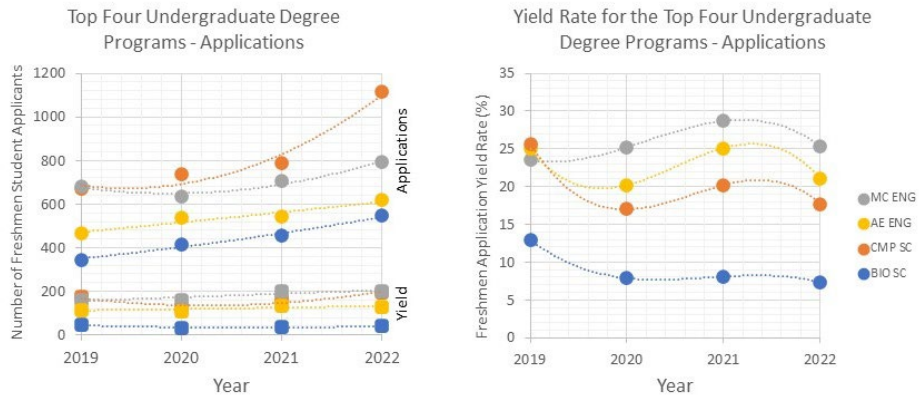


Figure 5: Number of first-time freshmen applications, yield (entering freshmen class size), and yield percentage for the top four undergraduate degree programs on the Missouri S&T campus based on overall application numbers.

Doctoral student recruitment and enrollment will depend on a combination of recruitment among our own undergraduate and master’s degree students as well as recruitment from undergraduate and master’s programs around the state (see section 3.C). We anticipate that our first doctoral students will be recruited from our own programs. Several current undergraduate and master’s students have expressed an interest. Once the program is established, we anticipate that at least half the students who enter the program will be recruited from other colleges and universities.

**Table 1a. Student Enrollment Projections** (anticipated total number of students enrolled in the program during the first five fall semesters following implementation.)

Year:	1	2	3	4	5
<b>Full-time</b>	3	6	9	12	15
<b>Part-time</b>					
<b>/Total</b>	3	6	9	12	15

**Table 1b. New Student Enrollment Projections** (anticipated number of students enrolled in the program during the first five fall semesters following implementation that are new to the University – that is, recruited from other universities.)

Fiscal Year:	1	2	3	4	5
<b>Full-time</b>	3	3	3	3	3
<b>Part-time</b>					
<b>Total</b>	3	6	9	12	15

Table 1c. Projected Number of Degrees Awarded

<b>Year:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>
<b># of Degrees Awarded<sup>1</sup></b>	0	0	0	0	0	3	3	3	3	3

<sup>1</sup> Time to graduation varies for Ph.D. students but should average 5-7 years, and 4-6 years for students who enter with and MS degree. We should begin to reach a steady state of new and graduating students by year ten or sooner.

### **3.B. Financial Projections**

A completed Pro Forma for the financial projections is included in Appendix 2.

#### ***3.B.1. Additional Resources Needed***

*Two new faculty lines* - The Dean of CASE has pledged two new tenure track faculty lines in the next five years as a key component of investments in life sciences initiatives. This pledge includes startup packages competitive with Biological Sciences assistant professors at R1 and R2 universities, and the startup packages are necessary to build research programs that will support this proposed Ph.D. program. These new faculty lines will be essential to expand research capacity in the Biological Sciences and to provide new faculty expertise in areas of molecular and biomedical science that have been identified as priorities for the life sciences initiative. New faculty members are already needed to meet the demand for biology collaborators with researchers in other departments, including several engineering programs. This demand for collaborators will increase further with the addition of a planned bioengineering doctoral program. These two new faculty members will also be required to address the need for three new proposed graduate courses for this doctoral program. Additional program growth in the Department will be dictated by total enrollment growth in Biological Sciences programs. The Department will aim to maintain the university average of 18:1 student to faculty ratio for biology majors within the department, and growth in program enrollments will provide resources to add faculty lines.

*Office staff support* - This Ph.D. proposal fits within the College of Arts, Science and Education plans to add three new doctoral programs (also including Psychological Sciences and Technical Communication). All three new programs will require new office support. At present, one office manager serves the Biological Sciences Department. The office manager's job duties include course scheduling, hiring and payroll management, ordering and package receiving (teaching and research), filing work orders, assistance with budget management (all department and faculty accounts), webmaster, social media posting, and office receptionist. A centralized solution within the college will be necessary to support growth in the Biological Sciences Department that will include enhanced research productivity and budget management as well as the new Ph.D. program. This additional office support is not included in the budget of this proposal.

*Expanded Research lab space and graduate student office space* – The west wing of Schrenk Hall was partially renovated in 2019. Planning for renovation of the east wing of Schrenk Hall is underway, with a commitment of \$27 million to the next phase of renovations of teaching and research labs, and faculty and student office space. These renovations are ongoing, and not included in the budget of this proposal.

A 'BioPlex' interdisciplinary life sciences and engineering research lab building has been proposed and recently added to the Campus Master Plan. The cost has been estimated at \$90-100 million. This building will provide life sciences research lab space and host interdisciplinary biomolecular and biomedical research for several departments, including Biological Sciences, Chemistry, Chemical and Biochemical Engineering, and Materials Science and Engineering. This new building will be integral to the expanded research lab needs of the Biological Sciences Department. This proposed new interdisciplinary building will serve future needs of researchers in programs across campus. It is not included in the budget for this proposal.

*Expanded budget for added departmental expenses* – The Dean of CASE has pledged that the department will receive additional annual budget support in the amount of \$1000 per graduate student to support expenditures like new student recruitment, student travel, publication costs, computer and software expenses, equipment replacement, and equipment maintenance and service contracts.

### ***3.B.2. Revenue***

Direct revenue from a doctoral program in biological sciences will come from three sources:

- Tuition dollars generated by sponsored support for graduate student research. We anticipate an increasing graduate enrollment to about fifteen doctoral students within five years of the initiation of the program, and we anticipate that one-third of graduate student support will come from sponsored research, fellowships, and other sources. Graduate students in our doctoral program will receive their summer support through research assistantships derived from external funding. The remainder of their support will come from teaching assistantships. Within five years, we anticipate fifteen doctoral students in this program with sponsored research tuition support contributing to program revenue.
- The increased capacity for research provided by a doctoral program will result in enhancement of overhead revenue from sponsored projects. We expect a boost in grant productivity resulting from growth of our department and enhanced research capabilities.
- Our focus on translational research and engineering and industry collaborations should result in patentable research outcomes.

### ***3.B.3. Net Revenue***

Doctoral programs are not net revenue generators. The one-time expenses for this program include investments in new equipment for the department, expended by new faculty using startup funds. Recurring expenses include salary and benefits for two new faculty members.

Table 2. Financial Projections for Proposed Program for Years 1 Through 5.

	Year 1	Year 2	Year 3	Year 4	Year 5
1. Expenses per year					
A. One-time					
New/Renovated Space					
Equipment					
Library					
Consultants					
Other (startup packages)			600,000		600,000
Total one-time	0	0	600,000	0	600,000
B. Recurring					
Faculty			\$80,000	\$82,400	\$169,744
Staff (50%)					
Benefits	0	0	28,496	29,351	60,463
Equipment (including software, computers, and equip. maintenance)	2400	4800	7200	9600	12000
Graduate Teaching Assistants	62,088	127,895	186,263	248,351	310,438
Library					
Other (recruiting and student travel)	600	1200	1800	2400	3000
Total recurring	65,088	133,895	303,759	372,101	555,645
Total expenses (A+B)	65,088	133,895	903,759	372,101	1,155,645
2. Revenue per year					
Tuition/Fees <sup>1</sup>	42,300	87,138	134,628	184,896	238,054
Institutional Resources					
State Aid -- CBHE					
State Aid -- Other					
F&A Funds Returned to the University					
Total revenue	42,300	87,138	134,628	184,896	238,054
3. Net revenue (loss) per year	(22,788)	(46,757)	(769,130)	(187,205)	(917,591)
4. Cumulative revenue (loss) <sup>2</sup>	(22,788)	(69,546)	(838,675)	(1,025,881)	(1,943,472)

1 - revenue based on 6 credit hours of tuition paid from sponsored research (GRA support) per student.

2 - these revenue projections reflect only the institutional investments in graduate assistantships and two new faculty. These projections do not capture the full benefits of expanded sponsored research that will be enhanced by this program and these new faculty.



### ***3.B.4. Academic and Financial Viability***

There are no financial concerns associated with this program. Academically, the program requires a minimum enrollment of 10 students to maintain a vibrant and active learning environment.

Table 3. Enrollment for Academic and Financial Viability

<b>Viability</b>	<b>Minimum Enrollment</b>
<b>Academic</b>	10
<b>Financial</b>	NA
<b>Overall</b>	10

## **3.C. Business Plan: Marketing, Student Success, Transition & Exit Strategies**

### ***3.C.1. Marketing Plan***

This program will be marketed towards undergraduate / master's level students with degrees in Biological Sciences and related disciplines. We will use a four-pronged approach towards advertising. First, we will utilize our website by enhancing faculty pages and creating videos of faculty interviews. Second, we will use social media, such as LinkedIn, Research Gate, Instagram, Twitter, and Facebook to advertise our program and openings in our Ph.D. program. Third, we will advertise via regional venues (e.g., MO Academy of Sciences, MoPhys, etc.) using email subscriptions, tables at conferences and meetings, and their websites. Lastly, we will advertise in academic and professional venues (e.g., American Society of Microbiology, American Society of Cell Biology, etc.) using the same methods as with the regional venues.

The graduate coordinator / chair will be responsible for marketing the program. That person will have help from a designated staff person in the department, who will help manage enrollment numbers, ensure campus paperwork is completed, track progress of students, and record student outcomes. There will also be a student ambassador who will help with social media posts. Campus branding will help the graduate coordinator develop media and optimize search engines.

In order to measure if the marketing strategy is effective, data will be collected on the number of recruiting events attended, the academic background of accepted students (including location of undergraduate institution, size of undergraduate institution, undergraduate major, etc.), how the applicants heard of the program, and number of views on social media posts.

As the program grows, marketing will change accordingly. In addition to videos of faculty, videos of graduate students will be posted on the departmental website. The successful outcomes of the students will be highlighted on social media, attracting more students to the program.

### ***3.C.2. Student Success Plan***

The Biological Sciences Ph.D. program at Missouri S&T will build on our existing strengths by enhancing collaboration among academic departments and research centers, UM-System campuses, and industry. The program will improve curricular and co-curricular coordination while supporting the engagement of all students in demonstrated high-impact teaching and learning practices. Support for graduate student learning and success will be infused across the curriculum and co-curriculum, and outcomes will be routinely assessed and tracked to help ensure ongoing improvement. Abundant campus resources and services—including the Student Success Center, Technical Editing Services, and the Writing Center—are dedicated to supporting student learning. Student persistence and on-time degree completion will be systematically addressed (see Monitoring Student Success below).

Our student success plan was developed around three core elements: academic development, career development, and social and emotional development.

#### *Academic Development*

The academic program will lead to the acquisition of the skills, knowledge, and attitudes needed to be effective scientists.

- Ongoing support and assessment of progress with mentor/advisor. Regular mentor/advisor interaction, Regular committee interaction
- Selection of rigorous courses linked to interest, skills, and career pathways
- Provision of timely intervention
- Learning experiences outside the classroom
- Progress in meeting rigorous expectations
- Interdisciplinary program with graduate certificate requirement

### *Career Development*

The student will investigate their own interests and abilities as they relate to the world of science in a dynamic economy. The one-size-fits all approach, which has driven academics for the past century, does not address the complex and varied needs of today's biologist. The customized plan of our Ph.D. program will include varied and flexible educational opportunities, personal connections, and elective coursework, and targeted support tied to each student's education and/or career goals. This plan will allow students to make better career choices with the academic foundation to achieve their career and personal goals.

- Attend professional meetings
- Career exploration activities
- Regular mentor/advisor interaction

### *Social & Emotional Development*

The Student Success Plan supports positive social and emotional development, allowing students to more fully engage in the school environment and take the risks necessary for optimal academic performance.

- Broadened awareness of self within a global context
- Utilizing supportive campus resources

### *Monitoring Student Success*

To ensure success of the program, students and faculty will be surveyed every two years for the first ten years, and then every five years after. Metrics on student activities will be kept by the Chair of Graduate Studies. The survey will include questions on:

- 1) Academic Performance. Academic performance refers to metrics that measure and track academic progress and achievement. GPA is a straightforward metric that correlates to student grades. First-year performance can indicate how well students are persisting through terms and predict the overall success in the students' program of study. Poor academic performance can affect other metrics such as retention and graduation rates, and lengthen time to completion, resulting in more time that a student stays in the institution.
- 2) Education and Career Goals. Tracking educational and career goals requires students to formally meet with an advisor each semester. Goals will be set (including presenting posters, outlining manuscripts, attending conferences, establishing a professional network, etc.). A workflow should be put in place that tracks the student's academic progress.

- 3) Time to completion. Time to completion is the time it takes for a student to attain the desired degree. This metric will allow the department to measure whether students are taking longer than the national average to complete their degrees, if there are extra courses, inefficient use of resources, or delays in availability of courses.
- 4) Passing preliminary exams.
- 5) Graduation Rates. Graduation rate refers to the number of students who achieved the degree.
- 6) Retention Rates. Retention rate refers to the number of students who persist through an academic program. This metric will help identify why students leave the program and help to uncover issues such as insufficient resources. High retention rates can lead to increased funding and elevated ranking to attract quality prospects and faculty.
- 7) Quality and accessibility of classes. Will be assessed through student evaluations and faculty peer observations.
- 8) Accessibility of required research equipment. Accessed by requests for new equipment and maintenance/repair of existing equipment.

#### *Student success in related programs*

The Biological Sciences Department has an enviable track record of success in developing innovative, distinctive curricula and creating opportunities for students to engage in high-impact practices. Our curricula provide a flexible, competency-based framework for curricular and co-curricular learning, and we are recognized for excellence in such areas as undergraduate research experience, service learning, and experiential learning.

Our B.S. and B.A. programs in biological sciences have represented the largest program in CASE/CASB since the inception of the college in 2014, showing that S&T has the capability to attract students interested in the biological disciplines. Our new B.S. degree in Environmental Science has exceeded enrollment predictions by double in its first year. This demonstrates that S&T has the infrastructure and reputation to continue to expand on an educational program in environmental biology, one of the three pillars in this proposal.

Of the 80 students to earn the Biomedical Engineering Minor (2016-2023) at Missouri S&T, over half (42) have earned degrees in Biological Sciences. In February 2023, a new Biomedical Engineering Design Team was formally recognized, and the team members include 40-50% Biological Sciences majors, with 40% of the officers being biology majors. This highlights that Biological Sciences is critical to the success of the biomedical science and engineering program initiatives on the S&T campus.

Another pillar in this proposal is an extension of one of our BioInnovation undergraduate certificate program. First offered in Spring 2020, the initial program had two teams

(consisting of 2-3 students) form Living and Learning Communities (LLCs), and since then, 30.6% of the teams pitched in a regional competition with 84% of those students winning, and one team filing a patent disclosure. Examples of undergraduate success include the [Bionic Bowel](#), [GuideLine](#), [Striae Away](#), [Foliograft](#), [Bertilde](#), [DentiGraft](#), and all three winners of the inaugural [Kummer Start-Up Challenge](#). All of these teams have won in competitions against teams comprised of medical students, graduate students, and practicing professionals. The BioInnovation track for our Ph.D. program will create a similar translational educational experience for our graduate students.

Our master's program currently has the highest number of enrolled students in its history, with a 50% increase from the previous year, an 80% increase from 5-years previous, as well as an 80% increase from 10-years ago.

### ***3.C.3. Transition Plan***

The primary responsible person will be the Director of the Biological Sciences Graduate Studies program, who is elected by the Biological Sciences faculty. Should the Director step down or be removed from the position, a new director will be appointed. This will ensure a seamless transition in recruiting, retaining, and matriculation of students.

### ***3.C.4. Exit Strategy***

If the program does not meet University expectations after ten years, the program will undergo remediation at the department level. The department efforts, led by the Chair of Graduate Studies, will begin the remediation by re-evaluating who is the target audience, examining advertising strategies, and identifying any misguidance in success outcomes and assessments of the program. We expect that by year 10, a minimum of 10 students will be enrolled at various stages in the Ph.D. program in Biological Sciences to achieve academic viability.

The decision to discontinue the program will be based on a discussion between the Department Chair, Dean, and Provost. At that time, current Ph.D. students can finish their program obtaining the same degree, but no more students will be recruited. Alternatively, Ph.D. students in Biological Sciences, will be merged with a department appropriate to their field of study (i.e., Chemistry or Bioengineering) where each student can finish their course of study.

## 4. Institutional Capacity

This program will be housed in the Department of Biological Sciences. Currently, this department supports undergraduate and master's degree programs in Biological Sciences, as well as hosting an interdisciplinary Environmental Sciences program. We anticipate that a doctoral program in our department will largely supplant our current thesis master's program in terms of redirection of existing and new graduate student support resources. However, the thesis master's program will continue to be supported as an alternative option that some graduate students may choose, as well as serving as a tool to recruit graduate students who may matriculate into the doctoral program upon completion of their theses.

## 5. Program Characteristics

### 5.A. Program Outcomes

*Campus Graduate Learning Objectives (GLOs) + program specific GLOs*

Students completing the doctoral program in Biological Sciences will have:

- an ability to apply knowledge of subject matter within the field of biological sciences.
- an ability to communicate effectively with scientists and non-scientists orally, in writing, and by other means.
- an ability to engage in productive critical thinking to solve research problems using a variety of approaches and integrating diverse disciplines.
- an ability to develop professionally as a biological scientist.
- an ability to independently identify, explain, and develop scholarship including a clear plan for addressing open research questions.
- an ability to exhibit ethical and professional conduct.
- developed skills to promote a climate of inclusion and engage with diverse members of the scientific community.

## 5.B. Program Design & Content

### *Curriculum*

The goal for this doctoral program will be to train leaders and experts in biological sciences pursuing a variety of paths leading to careers in industry, public policy and regulation, and academia. As the market share of academic jobs across all science domains has been in decline in the past two decades, it will be critical for our program to emphasize and train students to excel in non-academic career paths, which continue to grow. A focus on interdisciplinary training will be central to this goal. We envision our doctoral program to be divided into three complementary tracks (Fig 6) that reflect the breadth of our programs and the ambitions of the University vision for life sciences.

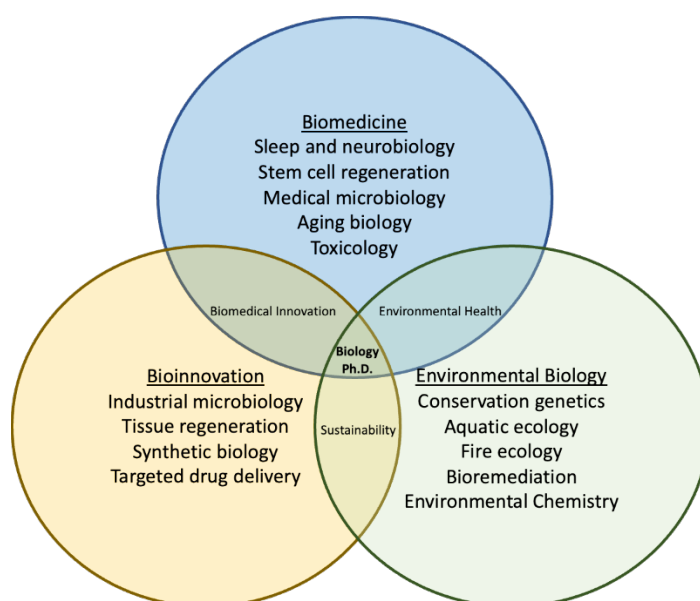


Figure 6: The doctoral program in Biological Sciences will support three tracks: Biomedicine, Bioinnovation and Environmental Biology. Listed under each track are research focal areas of present faculty.

The curriculum for this program will utilize existing coursework available to graduate students on the Missouri S&T campus. Some of the instructional effort required by this proposed Ph.D. program will result from a shift in focus from a department thesis-master's program to a new Ph.D. program. As a part of this transition, three new courses will be developed to serve as the foundation of each of our Ph.D. tracks. The faculty of the Biological Sciences anticipate developing these three courses as part of the regular, continuing, and ongoing process of revising, renewing and refreshing program curriculum. The addition of a new department chair (currently in process) and two new junior faculty in the first five years of this program (commitment from the Dean) will increase department capacity to offer the additional curriculum required by this Ph.D. program. Future growth of the department into the targeted areas of BioInnovation, Biomedicine, and Environmental Biology, will enable

the expansion of the curricular offerings. Equally important will be access by Biological Sciences Ph.D. students to cross-disciplinary courses offered in subjects including Chemistry, Chemical Engineering, Computer Science, Information Science and Technology, Materials Science and Engineering, Statistics, and others. Efforts to provide cross-disciplinary graduate student competencies include opportunities to pursue current and future graduate certificates, available at Missouri S&T and the other campuses of the UM System, in areas including data science, science entrepreneurship, and science communication, for example. Future certificates will be developed at S&T and certificates available online from the other campuses in the UM System, will also be promoted as options for our graduate students.

A critical component of the doctoral student curriculum in our program will be promotion of opportunities for our graduate students to pursue paid internships with industry and agency partners. We will develop an advisory board that will include workforce development leaders in the St. Louis and Kansas City areas to facilitate the connection of students with such opportunities. This will present a challenge for our faculty mentors whose research program momentum may be affected by the interruptions created when graduate students pursue these opportunities. However, we feel strongly that these opportunities are essential to the professional development of our students, and we are hopeful that such partnerships will also foster development of new collaborative opportunities for our students and faculty. Internships may be timed to coincide with the end of a student's data collection efforts during the period that the student is mostly analyzing data and writing, or internships could be scheduled near the beginning of a student's program before the student begins data collection. Flexibility between student and faculty mentor will be a key to success.

*Degree requirements:* Consistent with the Missouri S&T graduate catalog degree requirements, the Biological Sciences Ph.D. program at Missouri S&T will require 72 hours of graduate credit. For students who enter the program directly with a baccalaureate degree, this will include a minimum of 30 credit hours of 4000-, 5000-, and 6000-level lecture courses, and a minimum of 30 credit hours of graduate research. Students who enter with a master's degree will receive a block of 30 credit hours which will count toward the total seventy-two-hour program requirement. Students entering with an MS will be required to complete a minimum of 12 hours of 6000-level lecture courses, and 24 credit hours of graduate research. To maintain Ph.D. candidacy, a minimum GPA of 3.0 from 5000- and 6000-level courses is required.

A qualifying exam based upon a research proposal written and defended by the student will be successfully completed no later than the end of the fifth semester of enrollment, and a plan of study will be approved by a student's advisory committee by the end of the semester in which the qualifying exam is passed. A comprehensive exam will be completed after the student has completed their coursework. Upon conclusion of research, the student will complete a written dissertation and successfully defend the dissertation in their final exam (defense).

*Development of Degree Plan of Study:*

*Biological Sciences Degree Tracks:* Our program will be divided into three doctoral degree tracks, with a new Biological Sciences graduate course as the entry point of each track. Students will be able to choose between one of three graduate tracks: 1) Bioinnovation, 2)



Biomedicine, or 3) Environmental Biology. Each track includes one required course, two elective content area courses, and a proposal writing course (*minimum of 12 credit hours*). Additionally, all students enroll in graduate seminar at least twice (1 credit hour each), and graduate journal discussion at least once (2 credit hours each).

*Data Analytical Competency:* All students in the Biological Sciences Ph.D. program will complete a minimum of 6 hours of data analytic competency courses. Options include any graduate courses in statistics or any graduate computer programming, database management, machine-learning, or artificial intelligence courses (4000-, 5000-, and 6000-level). (*minimum 6 credit hours*)

*Professional Development:* All students will be required to complete a minimum of two semester hours of a graduate journal discussion (BIOSCI 6202) and two semester hours of a graduate seminar (BIOSCI 5020). Graduate students who are interested in industry career paths will be strongly encouraged to cultivate industry connections and to perform an industry-supported internship prior to graduation.

*Optional Non-Biological Sciences Graduate Certificate:* All students will have the option to earn a graduate certificate offered outside of the Department of Biological Sciences. Alternatively, students may develop a program of study that includes an equivalent amount of coursework in a focused area outside of Biological Sciences if a certificate is not available that meets the student's needs. Such a plan would be approved by the student's committee (*12 credit hours for non-biology graduate certificate*)

*Graduate Lecture Courses numbered 4000-, 5000- or 6000-level must sum to 30 Credit Hours:* The doctoral degree at Missouri S&T requires 30 hours of lecture coursework for students who do not already hold a master's degree. These minimum course requirements can be met through any combination of courses that fulfill one of the three Biological Sciences degree tracks, the Data Analytical Competency requirement, the optional non-biological sciences graduate certificate, and any additional elective courses selected to meet the 30-hour credit minimum. The requirement for students who already hold a master's degree is 12 hours, and those students may apply courses completed for the master's degree to meet the degree track and data analytical competency requirements.

### *Biological Sciences Graduate Track Requirements*

*BioInnovation Track* – Train students to design and develop biologically-related or biotechnological products geared for the marketplace.

*Required Course:* Advanced Principles of Biodesign (BIO SCI 6XXX)

*Elective Courses (choose two):*

Molecular Genetics (BIO SCI 4323)

Nanobiotechnology (BIO SCI 4666)

Bioinformatics (BIO SCI 5323)

Biomaterials II (MSE 6210)

Advanced Tissue Engineering (MSE 6240)

Advanced Stem Cell Biology (BIO SCI 6373)

Advanced Toxicology (BIO SCI 6383)

Bioremediation (BIO SCI 6463)  
Advanced Genomics (BIO SCI 6433)  
Advanced Microbial Metabolism (BIO SCI 6513)  
*Proposal Writing Course: Research Proposal Writing (BIO SCI 6223)*

*Biomedicine Track* – Train students to investigate and explore the processes that govern human health, development, and pathologies.

*Required Course: Current Topics in Biomedical Sciences (BIO SCI 6XXX)*

Elective Courses (choose two):

Advanced Tissue Engineering (MSE 6240)  
Biomaterials II (MSE 6210)  
Pathogenic Microbiology (BIO SCI 5313)  
Biology of Aging (BIO SCI 5343)  
Developmental Biology (BIO SCI 5353)  
Pharmacology (BIO SCI 5533)  
Bioinformatics (BIO SCI 5323)  
Virology (BIO SCI 5493)  
Advanced Cancer Cell Biology (BIO SCI 6353)  
Advanced Stem Cell Biology (BIO SCI 6373)  
Molecular Cell Biology (BIO SCI 65413)  
Advanced Toxicology (BIO SCI 6363)  
Advanced Genomics (BIO SCI 6433)  
Advanced Biomolecules (BIO SCI 6523)  
Advanced Neurobiology (BIO SCI 6533)  
Advanced Nanotechnology in Biomedicine (BIO SCI 6666)

*Proposal Writing Course: Research Proposal Writing (BIO SCI 6223)*

*Environmental Biology Track* – Train students to understand the complex interrelationships between living organisms and their physical and biological environments and to address complex biological questions that require the comprehension of multiple disciplines.

*Required Course: Current Topics in Environmental Biology (BIO SCI 6XXX)*

Elective Courses (choose two):

Advanced Global Ecology (BIO SCI 6563)  
Advanced Biodiversity (BIO SCI 5423)  
Environmental Microbiology (BIO SCI 6313)  
Advanced Freshwater Ecology (BIO SCI 6363)  
Population and Conservation Genetics (BIO SCI 5443)  
Advanced Toxicology (BIO SCI 6383)  
Geomicrobiology (BIO SCI 6343)  
Bioremediation (BIO SCI 6463)

*Proposal Writing Course: Research Proposal Writing (BIO SCI 6223)*

Non-Biological Sciences Graduate Certificates (examples):

Big Data Management and Analytics (COMP SCI)  
Professional Communication (TECH COM)  
Entrepreneurship and Technological Innovation (BUS)  
Life Science Innovation and Entrepreneurship (Mizzou, online)  
Health Ethics (Mizzou, online)  
Informatics for Public Health (Mizzou, online)  
Public Engagement (Mizzou, online)

Additionally, students in consultation with their committee may choose other graduate certificates outside of the Biological Sciences. Students may also construct their own non-biological sciences themed-course program of study from available graduate courses with committee approval.

Data Analytical Competency Courses:

Statistical Data Analysis Using SAS (STAT 5260)  
Regression Analysis (STAT 5346)  
Statistical Data Analysis (STAT 5353)  
Probability and Statistics (STAT 5643)  
Design and Analysis of Experiments (STAT 6344)  
Multivariate Statistical Methods (STAT 6545)  
Regression Analysis (COMP SCI 5204)  
Evolutionary Computing (COMP SCI 5401)  
Introduction to Data Mining (COMP SCI 5402)

Industry or Agency Paid Internship (optional):

BIO SCI 6085 Internship

Lists of Elective Courses Students May Take:

Elective courses offered in Biological Sciences  
BIO SCI 4323 Molecular Genetics  
BIO SCI 4393 Immunology  
BIO SCI 4663 Animal Behavior  
BIO SCI 5313 Pathogenic Microbiology  
BIO SCI 5323 Bioinformatics  
BIO SCI 5343 Biology of Aging  
BIO SCI 5353 Developmental Biology  
BIO SCI 5443 Population and Conservation Genetics  
BIO SCI 5493 General Virology  
BIO SCI 6210 Biomaterials  
BIO SCI 6240 Advanced Tissue Engineering  
BIO SCI 6313 Environmental Microbiology

BIO SCI 6343 Advanced Geomicrobiology  
BIO SCI 6353 Advanced Cancer Cell Biology  
BIO SCI 6363 Advanced Freshwater Ecology  
BIO SCI 6373 Advanced Stem Cell Biology  
BIO SCI 6383 Advanced Toxicology  
BIO SCI 6423 Astrobiology  
BIO SCI 6433 Advanced Genomics  
BIO SCI 6463 Bioremediation  
BIO SCI 6533 Advanced Neurobiology  
BIO SCI 6563 Advanced Global Ecology  
BIO SCI 6666 Advanced Nanobiotechnology

Elective courses in chemistry

CHEM 5001 Medicinal Chemistry  
CHEM 5610 Biochemistry  
CHEM 5620 Biochemical Metabolism  
CHEM 5630 Biochemical Nanotechnology  
CHEM 5710 Environmental Monitoring

Elective courses in Chemical Engineering

BIO ENG 6XXX Biomanufacturing (proposed)  
CHEM ENG 5250 Isolation and Purification of Biologicals  
CHEM ENG 5001 Drug and Gene Delivery  
CHEM ENG 5161 Intermediate Molecular Engineering  
CHEM ENG 5320 Introduction to Nanomaterials  
CHEM ENG 4210 Biochemical Reactors

Elective courses in Information Science and Technology

IS&T 5251 Management and Leadership of Technological Innovation  
IS&T 5520 Data Science and Machine Learning with Python

Elective courses in statistics

STAT 4210 Introduction to Statistical Data Science  
STAT 5260 Statistical Data Analysis Using SAS  
STAT 5346 Regression Analysis  
STAT 5353 Statistical Data Analysis  
STAT 5643 Probability and Statistics

Elective courses in computer science

COMP SCI 5204 Regression Analysis  
COMP SCI 5401 Evolutionary Computing  
COMP SCI 5402 Introduction to Data Mining

## 5.C. Program Structure

Students who enter the program directly with a BS degree will need to complete a minimum of 72 credit hours beyond their BS degree, which includes a minimum of 30 credit hours of 4000-, 5000-, and 6000-level lecture courses and minimum of 30 hours of research. A student entering with a MS degree can receive up to 30 credit hours toward their Ph.D., so that they would need to complete only the remaining 42 credit hours, including a minimum of 12 credit hours of 4000-, 5000-, and 6000-level lecture courses. Students will complete qualifying and comprehensive exams according to university guidelines as detailed above in section 5.B.

### 5.C.1. Program Structure Form

1. Total Credits Required for Graduation: 72
2. Residence requirements, if any: Not applicable
3. General education: Not applicable
4. **Major Requirements:** Total credits specific to degree: 72

Courses (specific course or distribution area and credit hours):

Course	Hrs	Course	Hrs	Course	Hrs
Graduate seminar	2	Research credit hours	30	Optional non-biology graduate certificate, or elective lecture courses.	12
Graduate journal discussion	2	Degree track required course	3	Data analytical competency	6
Proposal writing course	3	Degree track elective courses	6		

5. **Free elective credits:** Total free elective credits: 8
6. Requirement for thesis, internship, or other capstone experience:  
All students will conduct research and complete a dissertation. An internship (BioSci 6085 Internship) is optional.
7. Any unique features such as interdepartmental cooperation:

Students may choose courses from a variety of departments to complete their degree requirements. No specific interdepartmental cooperative agreements are proposed.

### **5.D. Program Goals and Assessment**

- Student progress will be assessed after completion of two years in the program by preparing and defending a research proposal submitted to their graduate committee and completion of an accompanying oral examination.
- Students will meet on an annual basis with their graduate committee to assess progress toward completion of their research program.
- Students will be assessed on their ability to engage with diverse disciplines by completing coursework for earning a graduate certificate in a program outside of biological sciences
- Students will be assessed for communication skills through participation in departmental seminars and through engaging in teaching for a minimum of one semester.
- Graduating students will be assessed by their graduate committee using the standard campus rubric for evaluating achievement of graduate learning outcomes.
- Graduates will be surveyed on a regular basis (at least once every 5 years) to assess their professional development and career preparation.

### **5.E. Student Preparation**

The target population for this program will be students who have completed a bachelor's or master's degree in Biological Sciences or a related undergraduate or graduate program. The course of preparative study will be dependent on the student's intended focal area of scholarship and the track (biomedical, bioinnovation, environment) the student chooses to pursue. The student's committee will determine if additional coursework is necessary for the student to succeed in their chosen track.

### **5.F. Faculty and Administration**

The individuals with primary responsibility for the success of this new graduate program will be the Graduate Program Director in Biological Sciences and the Department Chair of Biological Sciences. These positions are currently filled by:

- Director - Dr. Melanie Mormile, Professor of Biological Sciences
- Chair - Dr. David Duvernell, Professor of Biological Sciences

The curriculum required to support this new program is primarily in place, and currently supports master's students in Biological Sciences as well as graduate students in other programs who chose to enroll in these courses as part of their programs of study. All graduate courses supporting the proposed program will be taught by members of the graduate faculty.

Members of the Biological Sciences Department who are members of the graduate faculty:

1. David Duvernell - Professor
2. Chen Hou - Associate Professor
3. Yue-Wern Huang - Professor
4. Melanie Mormile - Professor
5. Dev Niyogi - Professor
6. Stephen Roberts - Professor
7. Andrea Scharf - Assistant Professor
8. Julie Semon - Associate Professor
9. Katie Shannon - Teaching Professor
10. Matt Thimgan - Associate Professor
11. Robin Verble - Associate Professor
12. David Westenberg - Curators Distinguished Teaching Professor

## **5.G. Alumni and Employer Survey**

We are committed to continuously gathering feedback from both alumni and employers to evaluate and improve the quality of this new program. Surveys and communication channels are utilized to collect relevant information, ensuring that the program meets the expectations and requirements of both alumni and employers. The following methods and schedules are used for collecting feedback from these key stakeholders:

### *Alumni Survey*

Method: Online questionnaires and mailed surveys are sent to alumni who graduated three to five years prior. The survey focuses on evaluating their satisfaction with the program and the extent to which it prepared them for their careers.

Schedule: Alumni surveys are conducted biennially, allowing for a comprehensive and up-to-date understanding of alumni perspectives.

Expected/desired satisfaction rates: The department aims to achieve a satisfaction rate of at least 80% among respondents, with the goal of continuously improving the program based on alumni feedback.

### *Employer Survey*

Method: Online questionnaires and surveys are distributed to employers of the program's graduates. The surveys seek to evaluate the preparedness and performance of alumni in their respective workplaces, as well as solicit suggestions for program improvements.

Schedule: Employer surveys are conducted every three years, allowing sufficient time to gather meaningful feedback while keeping the information current.

Expected/desired satisfaction rates: The department aims to achieve a satisfaction rate of at least 85% among employer respondents, using their input to adapt the program to better meet employer needs and expectations.

## **5.H. Program Accreditation**

This new biological sciences Ph.D. degree needs no accreditation to function but will be assessed together with other graduate degrees in the biological sciences graduate program via the Higher Learning Commission.

## **6. Appendices**

- Appendix 1: List of Participating Faculty (page 39)
- Appendix 2: New Program Pro Forma Biological Sciences PhD (page 40)
- Appendix 3: Letters of Support (page 41)
- Appendix 4: Response to External Reviews (page 53 )