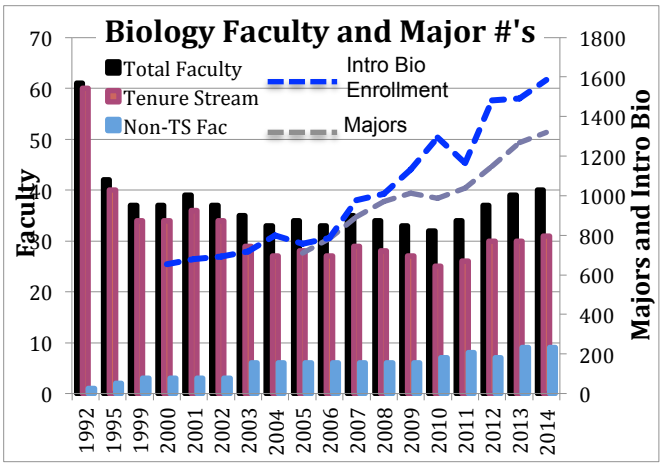
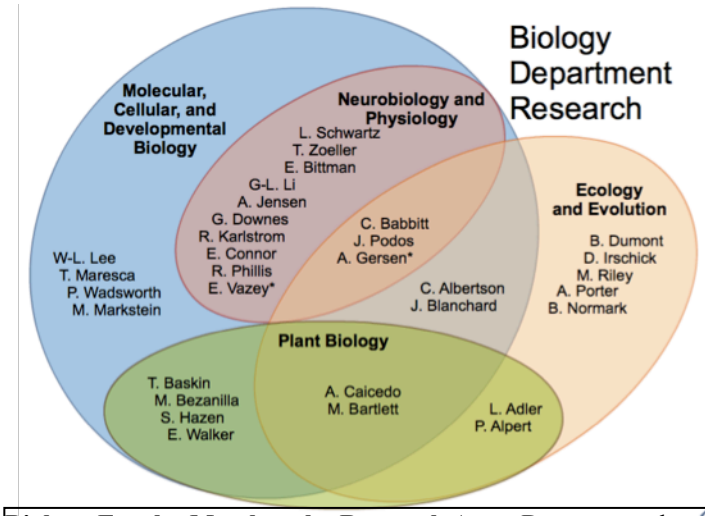
Biology Department Strategic Planning 2014: Stage 3, Part 1 (Environmental Scan)

Executive Summary

Biology is a broad life-sciences department with 30 tenure-system (TS) faculty members, 9 non-TS faculty (8 full time lecturers and 1extension), and 18 staff members. The department is well balanced by rank, with 6 Assistant Professors, 12 Associate Professors, and 12 Full Professors. Two new Assistant Professors will join the Department in 2015. The Faculty is 38% female and 13% ALANA. Thanks to vigorous hiring (15 TS and 4 Non-TS faculty) and the transfer of 4 faculty members from other departments, the department managed to grow slightly in the last 10 years, despite losing 16 members to retirement or transfers. During this time the number of Biology majors has nearly doubled to over 1300 and Biology is now the 2nd largest major at UMass. The Biology major is generally more diverse (59% female and 18% ALANA students for the 2013 class) than the campus overall. The ratio of declared majors to full time faculty is now 32:1 (38:1 when premed "majors" are included).



Research Mission Strengths and Challenges: As a broad Biology Department our faculty's research ranges from the level of molecules to the level of ecosystems, with research focused in four key areas: **Molecular, Cellular and Developmental Biology**, **Neurobiology and Physiology**, **Plant Biology**, and **Ecology and Evolution**. All graduate training occurs through one of the four interdepartmental graduate programs. Biology research is basic as well as strongly applied, and is making significant contributions to agriculture, medicine, and technology development, with major funding from a wide variety of government and private sources. Research expenditures remained at approximately $6M/year from 2006-2012 and diminished to $5M last year as the effects of the external funding climate began to be seen. Scholarly output and external awards are very strong despite the doubling of our educational mission. Biology faculty members greatly value our research breadth, as it helps foster interdisciplinary research. However, breadth also creates challenges in building depth and focusing research infrastructure. Biology's graduate program is inactive, raising issues of equity in resource allocation for faculty research.



Biology Faculty Members by Research Area. Departmental research is characterized by a breadth of research topics and extensive overlap between research programs. 32 research faculty are shown. (*the two TS faculty who will join the department in 2015.)

Education Mission Strengths and Challenges: Biology faculty members are leaders in science pedagogy and have been responsible for major improvements in life science training. Two large HHMI grants combined with several other educational grants to allow Biology to develop online resources for courses, introduce problem based approaches to large classes, and establish modern lab experiences and real lab research for a subset of our majors. Unfortunately, many of these resources are not available to all of our majors. Growth in the major and the number of honors students, along with growth in classes serving non-majors, are our most serious challenges. The Introductory Biology sequence has doubled in size over the last decade (see graph) and all of our classes have grown in step without the addition of new faculty members. While Biology is committed to improving the experience and outcomes of our majors, this is a challenge given large class sizes, barely adequate course offerings, issues with advising, and limited opportunities for undergraduates to perform research.

Research Environmental Scan

The Biology Department is positioned at the center of the life sciences in the college, with particular strengths in genetics, genomics, development, cellular imaging, and evolutionary approaches. Given the increasing complexity and expense involved in modern biological research, the Department has recognized that building strength within research clusters is critical for our faculty to remain competitive. The creation of research clusters positively affects productivity in many ways, including through collaboration and shared infrastructure. To maintain cohesion and interaction across clusters, our department has also focused recent hiring in "bridging" disciplines including Evolutionary Developmental Biology, Genomics, and Ecological Physiology. Interdisciplinary overlaps are extensive (see diagram above) and represent a clear departmental strength. At the same time, limited hiring opportunities and resources have made it difficult to build depth within the key clusters. Overall, our breadth of research is a strength, while maintaining depth is a challenge.

Research Environmental Scan: Investment of Choice — Intellectual mission and scholarly recognition.

Biology is clearly an investment of choice, with external research funding maintaining at approximately $5M and with significant internal investment in the form of laboratory renovations and start-up funds for new faculty. Again, breadth is a strength as it has allowed for a remarkable diversity in funding sources, and has the potential for interdisciplinary approaches that are likely to garner future funding. Depth is a challenge as biomedical research funding is increasingly targeted toward medical schools and other institutes with more explicit applied/translational research foci. Below we provide an overview of faculty scholarship and funding and describe the four research foci that are at or near critical mass in the Department.

Scholarly Sponsorship, Publications, and Awards

Biology research has been supported by major funding from numerous and diverse sources. These include, within the past five years alone, private foundations like the David and Lucile Packard Foundation and the March of Dimes; all primary federal agencies - NIH, NSF, NIFA, DOE, and DOD; and international sources such as the Human Frontiers Science Program and the European Union. Much of our research resides at the intersection of basic and applied science, and our faculty conducts work under numerous research agreements with local and national companies including sponsored research agreements with companies including Amarantus Biosciences, ImmuCell, Lilly, Pheromonicin Biotechnology and ReCommunity. Of particular note are 12 major grants from NIH and 24 from NSF over the last five years. Since 2010, pre-tenure faculty have also had significant success in attaining major federal grants/awards, which includes three NSF CAREER awards, a DOE Early Career Award, a K99 NIH Pathway to Independence Award, a NIH K01 career development award, and two NIH R01 grants.

Our department has excelled at successfully nominating individuals for college and university awards. We do not have formal mechanism to nominate faculty for external meritorious awards, in part because of the wide diversity of research areas. Nonetheless, recent notable research awards, many to junior faculty, include the Gerrit S. Miller Award from the North American Society for Bat Research, Marie Curie International Incoming Fellowship from the European Union, R.R. Bensley Award in Cell Biology from the American Association of Anatomists, Child Health Research Award from the Charles H. Hood Foundation, Basil O'Connor Starter Scholar Research Award from the March of Dimes, Women in Cell Biology Junior Career Recognition Award from the American Society for Cell Biology, and Harvard University Bullard Scholar.

Our scholarly output is high. Our research active faculty averaged 2.5 papers each year over the past five years. Many of these were published in high impact journals including *Cell*, *Current Biology*, *eLife*, *Genetics*, *Nature*, *Plant Cell*, *PLoS Biology*, and *Proceeding of the National Academy of Science USA*. A clear sign of established leadership in our fields are the numerous contributions to high impact *Trends* and *Annual Reviews* periodicals.

Translation and Entrepreneurship

Translational and applied aspects of our faculty's research tends to be overlooked, and the Department is well positioned to play a much bigger role in University initiatives in this area, including in the success of the Institute of Applied Life Sciences. Ongoing industry-sponsored research and translational projects include the identification of drug targets and therapeutics to treat cancer, skin and urinary tract infections, cow mastitis, and slow vision loss in human retinal degeneration diseases; increased nutritional content of cereal grains, and improved production and conversion of plant biomass to biofuels. Collaborative efforts with the UMass Medical School established the Institute for Drug Research and the Center for Microbiome Research. Biology is home to an expansive definition of entrepreneurship marked by imagination, initiative, and readiness to undertake new

projects. From scholarly research on geckos, phage, and gut microbes, our faculty have spun out three new start-up companies. These efforts have cracked the top five science breakthroughs of 2012 by CNN Money, won innovation competitions, and received support from NSF Innovation Corps and the CVIP Technology Development Fund. Our researchers have also worked with local companies on successful DOE and NSF SBIR phase I and II awards, helped raise venture capital, and established training grants with state biotech companies.

Research Foci at or Near Critical Mass

Neurobiology and Physiology: Neurobiology researchers study a wide range of topics at different levels of biological organization, from the single synapse to behaving animals. Reflecting this diversity, faculty have drawn graduate students almost evenly from both the Molecular and Cellular Biology (MCB) and Neuroscience and Behavior (NSB) interdepartmental graduate programs and utilize a range of model systems, such as moths, zebrafish, frogs, hamsters, and rats. Notably, four laboratories utilize zebrafish as a model system (Albertson, Downes, Jensen, Karlstrom) allowing for joint laboratory meetings and further development of this popular research model. Research can be further divided into two foci: Neuroendocrinology and Neural Development and Degeneration. Faculty in the area of Neuroendocrinology study circadian rhythms, pituitary patterning, and thyroid hormone regulation of brain development. This research cluster constitutes a key segment of the nationally recognized UMass Center for Neuroendocrine Studies, which had an NIH training grant and currently holds bimonthly meetings and an annual symposium. Faculty in the area of Neural Development and Degeneration study rod cell development and degeneration, forebrain patterning, locomotor network development and function, neural regeneration, and programmed cell death. This research cluster forms the natural campus home for the study of neural degeneration, which has been recognized by the college and the Institute of Applied Life Sciences as a promising area for future investment given its potential to attract extramural funding and bring together researchers across campus and at UMass Medical School.

Molecular, Cellular, and Developmental Biology: Cell and Developmental Biologists in the Department study diverse aspects of the structure and function of cells and how organs grow and develop. A breadth of research stems from the use of a broad range of model systems that include yeast, fruit fly, frog, zebrafish, and plant species that include moss, *Arabidopsis*, and *Brachypodium*. We also apply a wide-range of experimental approaches spanning biochemistry, molecular biology, genetics, high-throughput screening, and high- and super-resolution microscopy. The Cell and Developmental Biology group is actively investigating fundamental questions related to cell signaling, cell morphology and polarity, cellular differentiation and tissue organization, stem cell niches and genome plasticity, cancer cell biology, and cell division. Cell and Developmental Biology laboratories show particular strength in topics related to the cytoskeleton and molecular motors as well as to the establishment and maintenance of healthy versus disease tissues. The Cell and Developmental Biology group is a driving-force behind the development and expansion of emerging high- and super-resolution microscopy resources on campus such as spinning and scanning confocal microscopy, total internal reflection fluorescence microscopy, PALM/STORM super-resolution microscopy, correlative microscopy, and light sheet fluorescence microscopy, amongst others. These imaging modalities should underpin major new discoveries in the biological sciences over the next generation, and the Department is thus well-positioned to make significant contributions to their fields for years to come and to make UMass a destination of choice for future faculty and students that aim to use light microscopy.

Plant Biology: The Biology Department is home to an exceptionally strong group of researchers working in plants, who investigate key biological questions from the molecular level up through the ecosystem. The breadth of scientific questions is mirrored in the diversity of plant species interrogated by these researchers. There is particular strength in emerging model species, such as the non-vascular moss *Physcomitrella patens* and the grass *Brachypodium*. Researchers in these groups have developed resources for these species, which have been recognized nationally and internationally. One of our most recent hires conducts research that neatly spans two departmental clusters, Cell and Developmental Biology on the one hand, and Ecology and Evolution on the other, specifically focusing on the evolution of flower development in economically important grass species. The plant biologists have two major non-overlapping strengths: investigation of the molecular basis of cellular function and pattern using high-resolution light microscopy, and using natural variations together with modern sequencing technology to study the genetic basis of key traits, such as biofuel feedstock properties, nutrient transport, and the timing and development of flowers. This wide range of biological inquiry has allowed this group to coalesce around a central urgent problem in plant biology, the development of new models for biofuel feedstocks. Members of this group helped form the Brachypodium Consortium, a campus-wide group of researchers focusing

on developing this new model plant species for biofuels research. The Brachypodium Consortium has been instrumental leveraging funding from DOE, USDA, and NSF.

Ecology and Evolutionary Biology: Research on biological variation and the vast diversity of life flourishes within the Biology Department, particularly with the addition in the last five years of eight new ecology and evolution faculty (four having arrived from other CNS departments). Historical strengths in quantitative approaches to variation in behavioral and performance traits have yielded insights into diverse natural phenomena such as bird vocal communication signals, bat wing mechanics, and the abilities of geckos to climb vertical walls. By focusing on phenotypes and working back to genes, researchers are gaining a comprehensive understanding of how genomes affect organism survival in particular environments. Last year, five ecology and evolution faculty collaborated to publish a synthesis linking the study of phenotypic variation, genetics, and ecology. Faculty research programs leverage new DNA sequencing technology, computational methods, novel experimental approaches, and field studies. Questions of current interest include; How do bacteria evolve antibiotic resistance? Which genes underlie the evolution of adaptive traits in native plant and crop species? How do communities evolve in response to climate change? What genes influence the evolution of shape and form? How do evolutionary processes create patterns of genetic differentiation and phenotypic changes within and among different populations? How do multiple species interactions influence the evolution of phenotypic traits? These investigations embody the diversity of organismal life. Our research frequently requires larger collaborations and the expanding quantitative strengths of ecology and evolution faculty facilitated new projects with engineers and medical scientists.

Outreach and Community Engagement

Biology faculty members have founded and are actively engaged in numerous research and outreach efforts for the Commonwealth of Massachusetts. The Massachusetts Academy of Sciences, founded by faculty member Peg Riley, is devoted to the intersection of science, education, and public service and supports scientific research and education in areas relevant to the needs of the state. The STEM Diversity Institute oversees a comprehensive program of recruitment, retention and advancement activities focused on groups underrepresented in the science, technology, engineering and mathematics workforce. Numerous Biology faculty and graduate students participate in outreach programs that include visits to K-12 schools, with special emphasis on schools in Springfield. A particularly visible outreach program, founded by Biology graduate students, is the OEB Science Cafe. This program, going strong since 2011, feature interactions between scientists and the general public in the relaxed setting of the Esselon Cafe in Hadley.

Natural History Collections

As part of Biology's engagement with studying the diversity of life, our Department is charged with the maintenance, use, and growth of the Commonwealth of Massachusetts' Natural History Collections. These include tens of thousands of specimens ranging from living plants to insects to whales. The collections are an invaluable resource for integrated teaching, research, and outreach. Faculty conduct collections-based research supported by the NSF and Mellon Foundation; students get hands-on experience with the diversity of organisms; and the small fraction of the collections that are on public display are a perennial campus attraction for visitors. The collections are a College or University level resource but are financially supported by the Biology Department, with no clear budget model for their maintenance and growth. The collections are an underutilized strength for our teaching and research missions, but are a significant financial challenge, as there is currently no adequate budgetary support for their maintenance.

Buildings and Infrastructure

The Departmental recently dispersed across three distinct locations. The main offices and the majority of faculty are located in the Morrill Science Center buildings 2, 3, and 4So. Two faculty maintain laboratories in Fernald Hall, and three members recently moved to new space in the Life Science Laboratories (LSL). Extensive renovations over the last few years have vastly improved the research infrastructure in Morrill and allowed the recruitment of excellent new faculty members. There remains a great range in the quality of our laboratories, with several labs in Morrill and Fernald in particular being sub-standard. With the completion of a major third-floor renovation in 4 South next year, substandard labs remain in portions of the 4th floors of Morrill 3 and 4So, and these will need renovation for new faculty hires. The Natural History Collections lack environmentally controlled storage space, are scattered across buildings, and there are long distances between collections and collections-based classrooms and research laboratories. We have been challenged in recruiting our top faculty

candidates, particularly in the more resource intensive fields due to a lack of core facilities, and inferior start-up packages. To help overcome these challenges, the Department has relied on the Partner Employment Program to attract many of our faculty members (Vazey, Hazen, Caicedo, Bezanilla, Lee, Meyer).

Research Destination of Choice – Doctoral education

Biology mothballed its graduate program at the time these interdepartmental graduate programs were formed and Biology faculty members recruit and train graduate students through one of the four interdepartmental graduate programs (MCB, OEB, PB, and NSB). Instead of focusing on the specific prompts, we will therefore focus here on how the interdepartmental model for graduate education is a **strength** and **challenge** for the department.

The interdepartmental approach to graduate training is clearly desirable for many reasons and is appropriate given the interdisciplinary nature of life science research. When the new College of Natural Sciences formed from the merger of NSM, NRE, and the Department of Psychology, life science departments with their own graduate programs became part of the same college. The absence of an active Biology graduate program began to present new challenges in the new environment and as the major grew. As one example, Biology faculty request TA support for their graduate students through one of the four interdepartmental graduate programs. Unlike other departments with graduate programs, the Chair of Biology does not currently provide TA support to faculty members to establish or expand their research programs or provide a 'bridge' between grant funding. This creates significant disparities in the distribution of resources for faculty members in different life science departments, raising an issue of equity in support across the college that could affect faculty tenure and promotion (levels of TA support affect the size of research programs and thus research productivity). Furthermore, the four graduate programs each have distinct models for allocating TA support to graduate students, creating inequities in research support within the department. As an example, OEB faculty members receive one semester of TA support per year for their students, while MCB provides TA support for first year rotation students and Faculty members are expected to use TA support for their students only in exceptional circumstances. A third issue is allocation of Biology TAs to the faculty who train and teach within Biology. Although one would expect the Biology research mission to benefit from TA allocations that are generated to support Biology courses, this is not the case. Of more than 40 TAs assigned to Biology classes in the fall, only 13 will be students working in Biology research laboratories, highlighting the level of support that Biology is providing to the research programs of faculty in other departments. Overall, while interdisciplinary training is a Departmental **strength**, the lack of a departmental graduate program creates major challenges. Inequities in research support between Life Science departments is an issue that needs to be addressed.

Conclusions of Research Environmental Scan

The Biology Department is a vibrant home for scientists that appreciate the complexity of life that ranges from molecular interactions to ecosystems. We have research strengths in areas that align with all four interdepartmental graduate programs, and we distinguish ourselves on campus with concentrated expertise in cell biology, genetics, and evolution. Our breadth fosters interdisciplinary research and has allowed the department to hire in "bridging" fields such as Evolutionary Development (Evo/Devo) and Physiological Ecology. However, this broad distribution of research also creates challenges in building depth in particular areas and in focusing research infrastructure. External sponsorship remains high, but was diminished somewhat in the last year, while scholarly output and external awards remain consistently strong despite the doubling of our educational mission. Our research is both "basic" and strongly "applied", and is already making significant contributions to agriculture, medicine, and technology development. Biology can play an increasingly important role in the formation and success of the Institute of Applied Life Sciences, and we will continue our attempts to be a larger part of these discussions.

Overall, our ability to conduct research and train graduate students is becoming increasingly limited by our exploding undergraduate teaching mission (see next section), creating inequities among faculty in life science departments across CNS. Opportunities to teach specialized, smaller courses are limited and graduate level teaching has become almost non-existent for our faculty. Moreover, Biology faculty members have comparatively restricted access to TAs to support their graduate students. Scholarship will certainly benefit from a more equitable distribution of campus resources and undergraduate life science teaching duties.

Teaching Environmental Scan

Destination of Choice for Education

The UMass Biology Department is already a "Destination of Choice" at UMass, and is the second largest major in CNS and the University. The Biology curriculum is the only life science major on campus that integrates the cellular and molecular investigation of living organisms, including humans, with the study of the evolution and ecology of organismal biology. Students graduating with degrees in Biology follow numerous career paths including pursuit of graduate training, careers in health sciences, employment in life science research facilities and industries, and teaching.

Biology Curriculum

The Biology Department is committed to providing a curriculum based on learning goals that include both the acquisition of facts and concepts as well as the acquisition of skills and perspectives (http://www.bio.umass.edu/biology/undergraduate/learning-goals). Our goal is to prepare our students for a variety of career paths, but also provide them with the tools to be life-long learners in the rapidly evolving world of biological sciences. To achieve this, the course offerings in Biology begin with the gateway sequence of introductory biology courses (Bio 151, 152, and 153) that serve seven life science majors as well as students from across the University preparing for postgraduate degrees in the health sciences. The Biology Department is solely responsible for offering this introductory course sequence that includes a laboratory experience. Following successful completion of the introductory sequence (minimum grade of C), students choose from a variety of courses that range in topics from molecular biology and genetics to evolution and ecosystems. Enrollments in the Biology 200-500 level lecture-based courses range from 30-200; these courses serve our majors as well as students from across CNS. A subset of courses has lab or field experiences associated with them; Biology majors are required to complete two lab or field experiences above the 100 level.

Laboratory and field experiences provide rich opportunities for students to develop and hone the skills of practicing scientists. In 2006, we were awarded an Undergraduate Science Education Award from the Howard Hughes Medical Institute. With these funds, we developed a suite of honors and upper level inquiry-based laboratory courses. These courses have been offered each year since their inception and are noted for having high student satisfaction and in improving student skills and learning outcomes as measured by Classroom Undergraduate Research Experience surveys. Now, our challenge is to build on this experience to redesign the introductory lab course, Bio 153, into an inquiry-based research experience. The present configuration of the intro lab is not only more 'cookbook' in nature but also severely outdated in terms of techniques and equipment. Investment in this course redesign will have several beneficial outcomes in terms of student success and learning. First, such course experiences have been demonstrated to increase student learning, persistence in major, and graduation rates among students majoring in STEM disciplines. Second, redesign of the Bio 153 into a modern research experience that uses techniques and approaches appropriate for the 21st century will equalize the playing field for our incoming students, particularly those from economically-challenged rural and urban high schools. Finally, the redesigned course will better prepare all students to take advantage of upper level inquiry-based lab courses and independent research opportunities.

A fundamental aspect of a STEM education and predictor of STEM student success is participation in research activities. Our majors are more successful than their University or STEM peers in working on a research project with faculty and we have integrated authentic research into several of our laboratory courses. About 25% of our majors are members of the Commonwealth Honors College (CHC), and we are increasingly challenged to support our students who wish to complete honors theses.

In writing this document, we have drawn on many sources of information and begun to collect our own data on student satisfaction and outcomes. In addition to the Instructional Productivity data sets provided by the University, we recently ran focus groups of senior Biology majors with help from the Office of Institutional Assessment and Planning. We have carefully examined the grade distributions in our courses to identify and resolve grading disparities between sections of the same course and courses with high Drop-Fail-Withdrawal rates. We also met as a department to discuss the data and formulate recommendations for improving the student experience and success of our majors as described in our Recommendations document.

1. Program Attractiveness and Competitiveness

The Biology Department is successful in attracting highly qualified undergraduate students.

- Biology currently has 1,349 (this number changes frequently) undergraduate majors, the second highest in the University.
- Biology is a popular major, representing 5% of incoming students and 20% of CNS. Including pre-health majors across campus, 9.4% of incoming students enroll in our introductory course sequence.
- The past decade has seen a 299% change in application rates for Biology majors compared to 270% for CNS and 200% for the University.
- Biology attracts a highly select group of students. The average GPA for those who accepted offers of admission in 2013 was 3.88 for Biology majors, compared to 3.81 for CNS and 3.76 for the campus.
- Currently 25% of Biology majors are members of the Commonwealth Honors College (CHC).

Given our current resources, Biology is unable to recruit or attract additional majors; we are dissatisfied with our current ability to provide the excellent education that each of our majors deserves.

2. Overall Program Effectiveness

- The First Year Retention rate for Biology majors (2012 cohort) was 63.4% while another 26.9% had returned to the University as a different major for a combined retention of 90.3%.
- The Four Year Graduation Rate for the 2009 cohort who entered as Biology majors was 28.8% while an additional 38.9% of those entering students graduated in 4 years in another major. Taken together, the 4-year completion rate was 67.7%, on par with CNS and the University as a whole.
- A significant fraction of Biology graduates, ~ 40%, transferred into the major from either within or outside the University.
- Our majors are generally satisfied with their UMass experience but were more critical of their experience as a Biology major. Biology majors were less satisfied than their peers in CNS in rating their: Overall experience in your major, Access to classes in your major, Career preparation and guidance in your major, Connections to the rest of your academics in your major, and Writing preparation in your major.

The low satisfaction of our majors is likely strongly correlated with the size of the major and the resources we can bring to bear for their educational experience. The Biology faculty to student major ratio is 32:1 (38:1 when premed "majors" who become Biology majors in their second year are included) and >60% of our resources are spent on the introductory biology core sequence. Biology faculty teach more students and more sections than their CNS life science peers and in excess of the Delaware average and yet our majors earn more then 60% of their credits in classes >100, the second highest in the University. We have little information on the recruitment, preparation, and success of the large student population that transfers into the Biology major; these students may have particular issues that contribute to our dissatisfaction data but go unidentified. We have made several recommendations in our department plan (see below) aimed at improving student success and satisfaction.

3. Student Engagement

- The Biology Department utilizes several pedagogical approaches and techniques to increase engagement of our students in our courses, especially in large classes.
- By many measures, Biology majors perceive their learning and experience in their major on par with other CNS majors. In several instances however, their satisfaction levels are low compared to others. Biology ranks low in CNS in: Academic advising. Faculty concern for academic progress, Receiving useful feedback on their performance, and Stimulation of class participation by instructors.
- Of the credits earned by Biology majors who entered in 2009 and graduated in 2013, 15.8% were accrued in small classes (<30) and 62.7% in large classes (>100); the later was the second highest in the University. Biology majors have lost ground in these measures over the last 6 years. Biology CHC students experienced somewhat smaller classes.

The large number of Biology majors combined with our instructional resources makes it extremely challenging to engage our students. The majority of Biology majors are often seniors before they can enroll in Biology courses of less than 100 students. A small subset of majors participates in the suite of small inquiry-based laboratory courses that are enrolled by application. In order to enhance student engagement, success, and learning of Biology majors, it is critical that we improve our advising of our majors and that instructional resources in CNS be redistributed to better serve and engage all students.

4. Teaching Contributions and Effectiveness

- Senior exit survey data indicates that students have merely a "good" experience as Biology majors and would only "probably" choose UMass again.
- Biology scores at least 1 S.D. lower than the University average in these measures.
- Given our very large student to faculty ratio, it is not surprising that access to classes and advising were noted as particular problems by graduating seniors.
- We have a strong record of incorporating active learning innovative teaching methods into our many large classes, and this is reflected by better than expected SRTI scores in classes with >150 students.
- We have also, through HHMI Undergraduate Education grants, implemented a series of extremely successful introductory and sophomore level laboratory experiences focused on inquiry-based learning. The number of students reached by these classes remains small, owing to a lack of resources that would allow us to offer them to more students.
- Biology students rated that Biology courses "challenged them to do their best" higher than all other CNS majors but Microbiology and Physics.

The Biology Department has demonstrated success in implementing active learning approaches in large classrooms, introduced inquiry-based laboratory experiences into small courses, and invested in instructional methods to support student-centered learning. Despite active engagement of our faculty in the Center for Teaching and Faculty Development and several awards at the national, University, and College level for excellence in teaching, we have yet to fully transform the Biology curriculum into one in which all courses are active, outcome oriented, inquiry driven and relevant. We propose to increase our teaching effectiveness by encouraging the adoption of evidence-based teaching practices in <u>all</u> of our courses, increasing mentoring around teaching especially in the adoption of evidence-based teaching practices, and increasing our evaluation of student learning and teaching effectiveness.

5. Student Outcomes.

Biology majors are very effective at identifying research opportunities. Preparing students to compete for graduate training is a strength of the Biology Department.

- Our majors' overall self-assessment of their learning across Biology courses is on par with the average values for the University and CNS, as is our majors' assessment of the extent to which their experience contributed to important skills and habits of mind and their acquisition of their skills developed in writing, speaking, thinking critically, analyzing numerical information, solving problems, and acquiring work-related knowledge.
- The proportion of our students that reported working on a research project with faculty was much higher than the campus average (58% to 32%), and higher than for the average department in our college (49%).
- Our students tend to participate in certain high-impact non-classroom experiences, internships, community service, and study abroad at rates similar to University averages.
- More than one-third of our students report plans to attend graduate or professional school. Of that group, 35% plant to attend medical or dental school and 21% a Ph. D. program. All of these proportions greatly exceed campus averages, and are in the top tier in our college.

In these measures, we are not content with being average, but strive to excel. We believe that, in our faculty and staff, we possess skills, talent, and experience that could achieve excellence in student outcomes, if the resource limits that constrain us could be overcome. In the face of this challenge, Biology majors have shown themselves to be go-getters; they seek out and obtain research opportunities from across the campus and pursue postgraduate degrees in high numbers.

6. Effective Use of Resources.

Biology is exceptionally effective in its use of limited instructional resources and Biology faculty teach more undergraduates than their peers with less TA support for instruction based on number of majors.

Given the steady growth in the number of Biology majors over the last few years, Biology has already taken several measures to increase our teaching efficiency. We have had to deny teaching release for our faculty members in some administrative positions; the two Biology faculty members who serve as program directors/leaders of the OEB and PB interdepartmental graduate programs no longer receive a teaching release. In the past, we took class size into account in determining teaching load; a 150-400 student course was usually team taught by 2 tenure-track faculty members. Given our current enrollment pressures, we can no longer make this

accommodation; now tenure-track faculty members teach entire large enrollment courses (85-400) rather than just half. Finally, we have been forced to require that faculty members taking a one semester sabbatical be released from their light and not their heavy teaching load during their sabbatical year. Despite these measures, we are still unable to provide enough seats and a breadth of course selection for our majors. This ever-increasing teaching burden threatens our ability to remain competitive in fulfilling our research mission.

- The 2013 Delaware data demonstrates that both Biology Tenure Track (TT) instructors and Lecturers (L) taught more student credit hours/instructor (TT= 109%; L =126%) and more course sections /instructor (TT= 107%; L =100%) than all other life science departments in CNS (16%-93% for sections/instructor; 16%-104% for student credit hours/instructor). These data suggest that there in untapped teaching potential in CNS life science departments.
- The Office of Institutional Research Departmental Profiles data demonstrates that Biology has the highest Lecture Sections Taught/FTE Faculty for all CNS life science departments (Biology 2; all others 1.0-1.9). These data also suggest that there in untapped teaching potential in CNS life science departments.
- Biology allocates >60% of their TAs to serving the Introductory Biology core courses, leaving a TA pool for supporting courses for our majors that is far smaller relative to our student population than other CNS life science departments; in 2014-2015 we have a TA for every 88 majors. These data suggest that the current TA allocation system does not reflect the number of majors served by a department, resulting in a decrease in our ability to provide the best education for our majors.

Biology's instructional resources are stretched to the limit. Our faculty, on average, teach more undergraduates than our life science peers and receive less TA support for courses for our majors even though we are the second largest major in the University. We utilize tenure stream and teaching faculty very effectively, yet our faculty and students are dissatisfied with the number, size, and environments of the courses we can offer. Clearly, further investment in the Biology major is required to attain the improvements in student satisfaction and learning we hope to achieve. We have made several recommendations to realize this goal.

7. Diversity, Inclusion, and Access.

The Biology department is successful in attracting and supporting a diverse student population.

- In 2013, the Biology major was:
  - 59% female (compared to 53% for CNS , 49% campus).
  - 18% ALANA students (compared to 16% for CNS, 12% campus).
  - 33% first generation college students (compared to 30% for CNS, 25% campus).
  - 26% PELL grant recipients (compared to 28% for CNS, 22% campus).
- Biology is the home of 20% of the URM in CNS
- Biology faculty are involved in programs that address the success of students from diverse backgrounds:
  - BIOS, a bootcamp for entering Biology majors prior to the semester start
  - The Seminar Scholars course, Bio 292A (part of LSAMP)
  - STEM Ambassadors Program
  - The new ExSEL program for Biology 152

8. Internationalization.

- 17% of Biology majors study abroad.
- Biology faculty offer faculty-led courses where students travel abroad to conduct field research.
  - Bio 487H Tropical Field Biology
  - Bio 596Z Amazon Aquatic Ecology

9. Outreach and Community Engagement.

- 52% of Biology majors participate in practica or internships
- 60% of Biology majors are engaged in community service or volunteer
- The Massachusetts Academy of Sciences, founded and directed by a Biology faculty member, promotes public understanding of science through outreach activities.

10. Serving the Life Science Community

Biology serves the life science community and all life science majors by providing opportunities:

- BioTap: an Honors residential learning community of 48 first year students engaged in a 2 semester Honors introductory biology course sequence: Quantitative Biology of the Cell and Quantitative Systems Biology
- Junior Fellows in the Life Sciences Program: a year-long program that provides an invaluable opportunity for life sciences seniors to enhance their research experience through mentoring and professional development activities.
- Life Science Undergraduate Research Symposium: an annual poster session where undergraduate life science students present their research in the atmosphere of a scientific conference.
- Biology provides a third year iCONS class, Bio 383H Gene and Genome Analysis

Conclusions Of Teaching Environmental Scan

Our look in the mirror has been somewhat disheartening. We are a department known for its teaching excellence and innovation and our faculty teaches more students and more sections than our peer departments. Yet the data do not reflect our talent, our effort, or the realization of the kind of education we aim to provide for our students. We believe that this is a direct result of four things; 1) the tremendous growth of the life science student body and intro biology enrollments (in the last decade enrollments more than doubled from 1264 students in 2003-2004 to 2689 in the 2013-2014 academic year), 2) similar growth in the number of Biology majors, 3) increased demand for Honors experiences for Biology CHC students, and 4) the manner in which instructional resources are distributed within CNS. Biology's commitment to meet all student requests for the introductory biology course sequence and the demands of the CHC has resulted in a decrease in the instructional resources for teaching our majors and the opportunities we can provide them. This unsupported increase in our number of majors has had several serious consequences and is manifested in the low satisfaction of our majors in many measures.

We do not believe that a student's choice of major should determine the quality of their educational experience. Given the large number of students involved, further investment into teaching and training Biology students will have large impacts on STEM success, particularly the advancement of URM and women. We have several recommendations, described in the next section, that will, if implemented, share the teaching of the introductory biology core with other life science faculty, and allocate instructional resources more equitably to maximize the delivery of the best curriculum to all students.

Recommendations to Improve Undergraduate Education

Overview

The UMass Department of Biology is already a "Destination of Choice" at UMass, and is the second largest major in CNS. The Biology curriculum is designed to provide students with broad training across the disciplines in Biology, as well as the opportunity to specialize in a particular subdiscipline. With the large increase in the number of Biology majors over the last 10 years (~100% increase Biology majors, and a major-faculty ratio of 36:1), the current curriculum has begun to fail to function as designed; students cannot enroll in courses of their choice until their senior year, if at all, and they spend >60% of their time in classes >100 students. With this increase in majors, we also see that the students most in need of advising fail to seek it. As a result, our majors report limited access to courses, low satisfaction with advising, and less satisfaction with their major when compared to their peers in CNS.

The following recommendations are focused on addressing these issues and improving student learning and satisfaction. At the curricular level we propose to streamline the requirements for the Biology major to provide a more coherent curriculum that is easier for students to navigate. Within the classroom, we propose major investment in the introductory lab experience, and we will leverage the teaching expertise and leadership in the Department to spread "best practice pedagogy" more widely through our course offerings. Finally, we carefully examined the available data on student satisfaction and resource utilization across the CNS and propose structural changes in the life science majors that promise to greatly improve the quality of life science education overall while improving the Biology major and increasing student engagement, satisfaction, and success. The following seven recommendations are described in more detail below:

1. *Revise major requirements to form a more unified and coherent Biology curriculum.*
2. *Improve student learning and the classroom experience.*
3. *Improve and update the introductory life science core curriculum.*
4. *Engage our life science colleagues in teaching the introductory core course sequence for life science majors.*
5. *Engage the CNS community in identifying and negotiating strategies to provide advising and meet the needs of the increasing numbers of Commonwealth Honors College (CHC) students.*
6. *Standardize and allocate instructional resources to maximize the delivery of the best curricular experience for all CNS students.*
7. *Reorganize the existing CNS structure to provide a more unified framework for research and undergraduate training.*

Recommendation #1. Revise major requirements to form a more unified and coherent Biology curriculum.

Historically, the goal of "breadth" in the biology curriculum led to the creation of a suite of 200 level courses that follow the first year introductory sequence. Upper division classes were numbered in the 500 range, with very few intervening 300 or 400 level offerings. The large size of the major has led to oversubscribed courses at all levels, and particular challenges in 200 level courses, with many students taking these courses in their junior or senior years. This has led to a variety of problems in progression through the major, as well as much frustration on the part of our students. As a first step in improving progression through the major we propose to reduce the number of required courses and renumber our courses to provide a clear course order. We will reserve seats in 200 and 300 level courses for sophomores and juniors to ensure the timely progression of students toward graduation.

This will also allow for earlier identification of students who are unlikely to complete the Biology major successfully.

1A. Revise the Biology major required courses to:

- Biology 151, 152, 153 Introductory Biology Sequence (or Honors sequence)
- Biology 280 Evolution
- Biology 283 Genetics
- 2 Courses with Laboratory or Field Experiences
- 1 Plant and 1 Animal Course
- 19 Credits in courses at the 300 level and above
- Biology 494LI Life after Biology

1B. Renumber Biology courses to better reflect the sequence of the undergraduate curriculum and allocate seats in 200 and 300 level courses for sophomores and juniors.

- Biology 285 becomes Biology 385 Cell and Molecular Biology
- Biology 287 becomes Biology 387 Ecology
- Biology 288 becomes Biology 388 Introductory Physiology
- Many 500 level courses become the 400 level equivalent (e.g., Bio 523→ 423)

1C. Implement a Continuation Policy for the Biology major under which students must successfully complete Bio 151, 152, 153, 280, 283 and Chem 111, 112 within a set time frame in order to remain in the Biology major.

Recommendation #2. Improve Student Learning and the Classroom Experience

Biology is a demonstrated leader in evidence-based teaching and pedagogy as well as teaching excellence; several Biology faculty members have been awarded the Distinguished Teaching Award and CNS Outstanding Teaching awards. Although many Biology instructors have been both developers and early adopters of evidence-based teaching practices and class room technologies proven to improve student learning and engagement (clickers, team-based learning, blended courses, and flipped classrooms), we are ranked low compared to our peers in student satisfaction with the quality of teaching in the Biology major. While this is in part due to large size of the major and its classes, we note that evidenced-based teaching practices are not universally applied across our curriculum.

2A. Encourage the adoption of evidence-based teaching practices in all of our courses.

- Provide new opportunities for instructors to share their teaching approaches and successes.
- Support instructors in their efforts to adopt teaching strategies that are demonstrated to increase student learning and engagement.
- Work with the Center for Teaching to improve teaching effectiveness and educate all instructors in evidence-based teaching practices.

2B. Increase mentoring around teaching especially in the adoption of evidence-based teaching practices.

- Partner junior faculty members with effective instructors in team teaching a course using evidence-based teaching methods.
- Formalize more robust mentoring relationships for junior faculty around research and teaching .

2C. Increase the evaluation of student learning and teaching effectiveness.

- Establish course specific learning objectives for all courses.
- Develop evidence-based assessment methods to measure student learning.
- Develop a mechanism for departmental review of student learning in courses.

Recommendation #3. Improve and update the introductory life science core curriculum

The Biology Department has defined learning goals for Biology majors that include both the acquisition of facts and concepts and the acquisition of skills and perspectives (http://www.bio.umass.edu/biology/undergraduate/learning-goals). These learning goals not only prepare our students for a variety of career paths, but also provide them with the tools to be life-long learners in the rapidly evolving world of biological sciences. The current curriculum offers several upper-level learning opportunities in and outside of the classroom where students gain these skills and perspectives as they investigate real-world problems in authentic research projects. Unfortunately, the current introductory biology curriculum does not prepare our majors to participate in these experiences, and there are only enough slots in these upper level research-based courses to serve a very small proportion of our majors. The steps recommended here aim to provide life science majors with a modern class-based authentic research experience in the first year. We also propose to build on the skills learned in the recently rejuvenated Bio 153 laboratory experience by developing a sophomore level laboratory course for biology majors. Implementation of this recommendation will greatly enhance the preparation of our entering students for research, reinforce the skills laid out in the Learning Goals for Biology Majors, and produce a student body better prepared to engage in upper level courses and more competitive in their pursuit of careers in STEM disciplines.

3A. Redesign the Biology 153 laboratory course into a modern research experience that uses techniques and approaches appropriate for the 21st century.

3B. Develop and offer a 200-300 level Genetics and Evolution Laboratory course for Biology majors.

3C. Invest in the personnel, laboratory space, equipment, and supplies to achieve the redesign of Biology 153 and the Genetics and Evolution Lab in a way that provides continuity and stability for these course offerings.

3D. Hire an additional Biology Lecturer to allow the implementation of these recommendations, meet serious current unmet curricular needs, stabilize curricular offerings and capacity, and ensure the continuity of the curriculum.

Recommendation #4. Engage our life science colleagues in teaching the introductory core course sequence for life science majors.

The Department of Biology has primary responsibility for teaching the introductory core curriculum for all life science majors in the College of Natural Sciences and for students preparing for careers in health professions across the campus. The enrollment in introductory Biology courses has grown tremendously in the last 6 years as we responded to the growth in students requiring our courses; e.g; enrollment in Bio 151 increased by over 600 students since 2009. There is also high demand for our courses by students in other majors. With this large influx of students has come a concomitant increase in the number of students who take our 200 level classes. All of these classes are now very large (100-200 students), producing the undesirable effect that our majors spend the majority of their time in classes with more 100 students. The allocation and investment of departmental resources into the training of life science and pre-health professionals compromises our ability to provide a high quality upper level curricular experience for our majors.

Biology is a destination of choice for freshmen interested in the life sciences given their familiarity with the discipline in high school, but many change their major in the second or third year at UMass; 29% of entering freshmen Biology majors graduate as Biology majors after 4 years while 39% graduate in another major in this same period. This clearly illustrates that the Biology Department has primary responsibility for teaching and advising many students who subsequently change majors. Another group taught and frequently advised by the

Biology Department are students initially enrolled in the artificial Premedical and Predental majors; in 2012, >250 students enrolled with these majors. Taken together, the time and resources the Biology Department invests in the teaching and advising of students who are not or will not remain Biology majors severely detract from our ability to serve our own Biology majors. We believe this is manifested in the low satisfaction of our majors in their major experience, their perception of lack of faculty concern for their academic progress, their lack of access to classes, and their dissatisfaction with our advising.

Analysis of the Instructional Productivity data sets provided by the University for this planning process indicates that there is untapped teaching capacity among CNS life science departments. We recommend mining this teaching talent to help establish an independent educational unit focused on introductory life sciences education. Based on similar programs established across the country, we feel that the creation of a new unit dedicated to introductory life science pedagogy, in combination with improved networking and mentoring of faculty, will improve the undergraduate experience and increase student satisfaction across the life science majors.

4A. Form an independent unit (e.g. the Introductory Life Sciences Program) to teach and advise life science and pre-health professional students in the introductory life science core curriculum.

- Integrate instructors from participating life science departments in the teaching of the introductory life science core curriculum especially from those departments with under-utilized teaching capacity

- Design and teach a unified introductory life science core curriculum with core concepts, learning objectives, and assessment methods in collaboration with participating life science departments

4B. Create a CNS-based supportive network for the mentoring and career development of Lecturers. This is a critical need, as Lecturers taught 80% and 73% (respectively) of all introductory Biology and Chemistry students in 2012-2013.

Recommendation #5. Engage the CNS community in identifying and negotiating strategies to provide advising and meet the needs of the increasing numbers of Commonwealth Honors College (CHC) students.

In the 2013 Senior Survey, a majority of students in only 3 of 14 CNS majors report that they are 'very satisfied' with the academic advising they received. The success and popularity of the Commonwealth Honors College has raised the metrics of entering students and is largely responsible for the advancement of UMass in college rankings. Based on this success, there is pressure to increase the enrollments of CHC students without a commensurate increase in resources to departments who are asked to provide small enrollment courses and independent thesis experiences for these students. Growth of the CHC student body within the current CHC model of resource allocation is unsustainable and threatens the success of CHC.

5A. The CNS community should identify successful advising strategies that can be applied across departments with differing numbers of majors and secure needed resources to improve the quality of advising.

5B. CNS community should collaborate to negotiate a sustainable approach for meeting the needs of increasing numbers of CHC students without compromising the education and experience of non-CHC students.

Recommendation #6 Standardize and allocate instructional resources to maximize the delivery of the best curricular experience for all CNS students.

Biology has standardized the teaching load for Teaching Assistants (TAs) and has recently developed a policy for assigning TAs aimed at increasing the quality of the undergraduate curricular experience. This method of allocating TAs has resulted in an increase in writing in our courses, inclusion of open-ended response questions on exams in large classes, an increase in lab experiences, and the addition of hands-on-exercise opportunities in lecture classes. The current Biology TA allocation however, mainly serves the introductory biology courses; >60% of Biology TAs are assigned to introductory courses. The remaining Biology TAs available for teaching our majors beyond introductory courses results in a ratio of Biology majors/TA of 88 for 2014-2015, arguably the highest in CNS. There is great disparity across CNS in the workload and distribution of TAs to courses, with Biology likely having the highest TA workload and the lowest level of TA support for courses. This unequal distribution of instructional resources within CNS is one factor contributing to the documented dissatisfaction of Biology majors with the effectiveness of teaching in the major and measures of faculty concern for their academic progress, receipt of useful feedback on their performance, and access to faculty.

6A. Standardize the TA workload for CNS TAs and use the standard to assign TAs across the College.

6B. Standardize the allocation of TAs to courses and provide for the equitable distribution of TAs in CNS in order to normalize instructor support and maximize the delivery of the curriculum.

Recommendation #7 . Reorganize the existing CNS life science majors to provide a more coherent framework for research and undergraduate training.

The current CNS departmental/major structure is a product of history, most notably the merger of two colleges (NSM and NRE) that each contained life science majors. The formation of a School of Life Science (or School of Life and Chemical Sciences) would unify the life science community. A School of Life Sciences will expand opportunities for the life science community to create more unified and coherent undergraduate programs, to marshal and direct resources toward common goals, and to improve student learning and success.

7A. Form a School of Life Science (or perhaps a School of Life and Chemical Sciences)

7B. Have all life science-oriented students enter UMass as “life science” majors and declare specific majors at a later date.

7C. Restructure majors to better serve students’ interests and to provide modern, unified, coherent curricula. Many possible groupings of majors could be generated to meet student need and unify instructional expertise. Possible majors could include: General Biology; Evolutionary and Ecological Biology; Cellular, Genetics, and Developmental Biology; and Neuroscience and Physiology.

7D. Consider reorganization of CNS unit structure as needed to provide vertical alignment and support to best achieve curricular goals.