

VISION FOR PLANT BIOLOGY AT UMASS

Report to CNS Dean Steve Goodwin and Associate Dean Sally Powers
April 13, 2016

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Introduction

The “**Plant Visioning Committee**”, chaired by **Elizabeth Vierling** (Distinguished Professor, Biochemistry & Molecular Biology) and **Michelle DaCosta** (Associate Professor, Stockbridge School of Agriculture), was charged by CNS Dean Steve Goodwin to develop a holistic picture of plant biology at UMass Amherst, evaluating research strengths along with undergraduate and graduate training. The overall goal was to make recommendations on how to further develop and enhance the world class reputation of both the basic and applied disciplines of plant biology at UMass and on how to create synergisms across the basic and applied plant sciences. A critical component of these recommendations is a plan for strategic hiring of new faculty.

Toward achieving these goals, we convened a committee with representatives from different sectors of plant biology on campus with the following members:

Lynn Adler – Professor, Biology

Magdalena Bezanilla – Professor, Biology (joined 2016)

Daniel Cooley – Professor, Stockbridge School of Agriculture

Samuel Hazen – Associate Professor, Biology (2015 – on sabbatical Spring 2016)

Geunhwa Jung – Professor, Stockbridge School of Agriculture

Frank Mangan – Extension Associate Professor, Stockbridge School of Agriculture

Jennifer Normanly – Professor and Head, Biochemistry & Molecular Biology

Tristram Seidler – Extension Assistant Professor & Herbarium Curator, Biology

Kristina Stinson – Assistant Professor, Environmental Conservation

Process:

The committee assembled data on the current faculty in plant sciences and their research support, the numbers of graduate students engaged in plant biology research, and the courses offered at both the graduate and undergraduate level that address issues in plant biology. We also developed an inventory of the facilities and resources that support plant biology at UMass, and special events and activities that are initiated by and involve the plant biology community on campus.

Based on the data gathered, the committee developed a picture of the strengths of plant biology at UMass and recommendations to increase the research and educational impact of UMass Plant Biology at international and national levels. These recommendations address several different areas:

- Faculty hiring
- Resource enhancement and maintenance
- Student recruitment and training

In all categories the interest in enhancing interactions across basic and applied plant sciences were considered.

Recommendations for Faculty Hiring in Plant Biology

As directed by CNS Dean Steve Goodwin, the committee developed recommendations for investments in new faculty positions that will complement existing strengths and build synergisms between faculty and departments working in basic and applied plant sciences. ***As the flagship campus of the UMass system and the state land grant institution, UMass should be the leading force in basic plant science and agriculture in the Northeast.*** We note that building in the plant sciences is a high priority at our peer or aspirant institutions, and we have attached recent advertisements from Michigan State University, University of California Riverside, Purdue and North Carolina State University, where cluster hires are in progress (Appendix). ***The committee also notes and is concerned that on the order of 12 plant biologists (in SSA, BMB and ECO) are likely to retire within the next five years.***

UMass currently has a diverse core of faculty working in basic plant science research in the Biology (BIO), Biochemistry & Molecular Biology (BMB), Environmental Science and Conservation (ECO) departments and the Stockbridge School of Agriculture (SSA). A strength of this group of faculty is that their research spans from molecules to ecosystems. ***In the last five years the plant biology faculty on campus have brought in on the order of \$40 million in competitive grants and contracts*** (formula funds not included in this calculation). We believe that with strategic hiring and enhanced synergisms across campus this success can easily be doubled. In considering positions, the committee identified areas with immediate and long term potential for impact and areas in which we believe UMass could take a leadership role by building on our current human and physical resources. ***A major goal of the recommended hiring effort is to better bridge between the basic and applied plant sciences.*** UMass is located in a regional hub of agriculture, as Hampshire and Franklin counties have the highest percentage of farmland other than Plymouth and Dukes counties in southeastern MA, and also have a major share of greenhouses and nurseries. In addition, at \$48 million (2012 value), MA ranks 5th in the nation for direct market sales of farm products. ***Linking the basic and applied plant sciences at UMass is an important goal for enhancing student training, success of external funding requests, and serving the local community and greater commonwealth.***

We identified two areas in which to recommend cluster hires of four new faculty members each, at either the junior or mid-career level. The two areas focus on metabolic processes unique to plants and on the impact of plants on both the environment and human health: 1) Photosynthetic Carbon Metabolism, the primary source of all food and natural fibers, as well as the major component of the global carbon cycle, and 2) Specialized Plant Chemistry and Metabolism, defined as the production of diverse and unique plant small molecules that serve as signals within and between plants and other organisms and that have been the source of important medicinal and industrial compounds.

We seek to hire individuals into each of these areas to address problems from the ecosystem to molecular level and from the basic to applied. By proposing a cluster hire, we aim to achieve critical new intellectual strength and visibility, while synergizing with existing faculty and facilities. The new CNS greenhouses, along with new core facilities in IALS, particularly in mass spectrometry, biophysical characterization, microscopy and genomics, are key resources that would support research in these areas. Individuals with a broad vision of the many facets of these fields could apply cutting-edge technologies and would have multiple possibilities for interactions on campus, as well as many avenues to obtain research funding (USDA, NSF, EPA,

DOE, and NIH depending on research focus). Bringing new faculty to UMass is an opportunity to achieve interactions across disciplines on campus and solidify the university's leadership role in this mandated area of a land grant institution.

The vision for faculty hiring was discussed extensively by the Visioning Committee, discussed with all plant biology faculty and the Chairs of BIO, BMB, SSA and ECO, and then with each department (discussion with Biology Department still pending). *All department chairs enthusiastically supported these recommendations as consistent with departmental strategic plans.*

CLUSTER HIRE: PHOTOSYNTHETIC CARBON METABOLISM

Climate change and food security are undoubtedly two of the most important issues facing the world today. The future of our society and food supply depends on understanding the feedback between vegetation and the climate system and resulting impacts on the global ecosystem and agriculture. Through photosynthesis, plants play a crucial role in converting carbon dioxide into biomass, cooling the climate, and providing the foundation of all available food resources. To meet food and fuel demands of an increasing human population, global food production will need to increase more than 50% before 2050. At the same time, forested ecosystems of the Northeastern USA region are a major terrestrial sink for atmospheric CO₂, and thus play a critical role in the global carbon cycle and hence global temperature. Better understanding of the carbon sink strength in both agricultural and natural ecosystems is a key to reducing uncertainties about food supply, as well as future levels of atmospheric greenhouse gases. In addition, biomass production in crops and natural ecosystems significantly varies due to genetics, climate, and management practices. Therefore defining the biochemical, physiological, agronomical, and environmental factors needed to maintain or increase productivity and sustainability of agricultural systems is needed while mitigating the unprecedented negative impacts on the environment related to food production and deforestation.

Opportunity for UMass:

Photosynthesis is central to the study of plant biology. To be a destination recognized for plant biology research we need a group of faculty working on this fundamental aspect of plants. While there are a number of centers focusing on light energy conversion in photosynthesis, there is an open opportunity to make an impact in the area of carbon metabolism. This field encompasses multiple areas with significant overlap in and across UMass departments providing critical synergies and bridges. Importantly, there are significant funds at the federal level to support work in these areas in both agriculture and basic science due to the national priorities on climate change and food security.

We recommend filling four tenure track positions at the Assistant or Associate Professor level in the area of photosynthesis related to carbon capture, utilization, and storage. Research areas targeted include, but are not limited to: biochemistry of primary carbon metabolism, source sink relationships, agricultural productivity, and the impact of environmental stress and climate change on photosynthesis. Candidates addressing ecosystem function, fundamental mechanisms of carbon metabolism or agricultural production, as well as candidates combining experimental work with computational modeling would be a major asset. Our goal is to hire scientists that exhibit a broad vision of how his or her research links to the discipline of plant biology from the cellular and molecular levels to the agricultural and natural ecosystem levels, and who are

interested in building a research program that synergizes with other plant biologists on campus. Depending on the candidate's expertise, the primary appointment could be in life science areas currently encompassed by BIO, BMB, SSA or ECO.

In seeking to span from the molecular to ecosystem and basic to applied, a general vision for positions is given below:

Biochemistry & Molecular Biology: Research on the structure, function, and/or regulation of molecular components involved in plant carbon metabolism, employing one or more structural approaches (crystallography, mass spectrometry, NMR, modeling) or systems level metabolomics are of major interest.

Biology: Research focusing on deciphering the cellular and/or physiological mechanisms controlling carbon metabolism in plants, using a variety of approaches including but not limited to quantitative genetics, high-end cellular imaging, molecular genetics, and physiological studies.

Stockbridge School of Agriculture: Research focusing on exploiting enhanced carbon metabolism traits to improve the resilience and sustainability of crop plants in a changing climate. Areas of interest include understanding mechanisms controlling carbon metabolism to maximize crop productivity in field environments, integration of carbon metabolism with nutrient dynamics, biotic/abiotic limitations, and genomic resources in plants.

Environmental Conservation: Research on biological processes in temperate forests, at both the whole ecosystem (e.g. carbon sequestration and greenhouse gas fluxes) and individual organism (e.g. carbon allocation and phenology) levels, using tools from ecophysiology and forest ecology, biogeochemistry and process-based modeling, biometeorology and atmospheric science, and applied mathematics, statistics and computer science.

CLUSTER HIRE: SPECIALIZED PLANT METABOLISM

Plants produce a huge diversity of small organic chemicals that are called “secondary”, or more recently “specialized” metabolites. These natural products, which number well over 200,000 different molecules, serve many important roles. As pigments, scents and flavors they attract pollinators and seed dispersers. They can be signaling molecules for symbiotic interactions or serve to deter pathogens or herbivore. As products secreted into the environment they influence the composition of the phytobiome, which is increasingly recognized as a critical factor control plant health and productivity. Thus, specialized phytochemicals orchestrate plant interactions with the agricultural and natural ecosystem and are critical to plant survival and fitness. Furthermore, such compounds are the source of numerous medicinal and industrial products that have been exploited by society for millennia. Identification, production and use of natural products is a fast growing field of plant sciences with tremendous potential for innovative research in improving sustainable agriculture, human health and the global economy.

Opportunity for UMass:

We recommend filling four tenure track positions at the Assistant or Associate Professor level in the area of the biochemistry, physiology, ecology or biology of bioactive plant compounds. Areas on interest include, but are not limited to biological chemistry of natural products and their

biosynthetic pathways, impact of plant compounds on the phytobiome in agricultural or natural ecosystems, impact of phytochemicals on trophic interactions, and production of crops with enhanced nutrition. Because of the direct link between photosynthetic metabolism and production of specialized metabolites, these four positions should also synergize with the hires in primary carbon metabolism.

A new faculty member in this area would also be expected to act as a strategic leader in leveraging IALS investments in new instrumentation in the core facilities, the recently acquired plant cell culture collection, and the computing power of the Mass Green High Performance Computing Center. An individual with a broad vision of the many facets of this field who could apply cutting-edge technologies would have multiple possibilities for interactions on campus, as well as many avenues to obtain research funding (USDA, NSF, EPA, DOE, and NIH depending on research focus).

In seeking to span from the molecular to ecosystem and basic to applied, a general vision for positions is given below:

Biochemistry & Molecular Biology: Research into the biological chemistry of natural products with insight into the structure and function of natural products and the enzymes in their biosynthetic pathways, along with a vision for how systems biology can inform research and innovation in this field. Metabolic engineering of plant systems for commercial applications in agriculture or other industries could also be a focus.

Biology: Research into the ecology or biology of bioactive plant compounds structuring species interactions. Areas of interest include, but are not limited to interactions between plants and their pollinators or herbivores, as well as signaling between plants and their pathogens and/or symbionts. Research should be strongly grounded within evolution/ecology or molecular/cell biology, incorporate cutting-edge technologies to address questions at multidisciplinary levels.

Stockbridge School of Agriculture: Research into the role of plant secondary metabolism for maximizing plant health and productivity in agricultural or urban systems. Areas of interest include, but are not limited to understanding and exploiting interactions within phytobiomes that influence plant, soil, and agroecosystem health; role of secondary metabolites in shaping plant responses to biotic and abiotic factors relevant to climate change; and production and use of new bioactive compounds for new crops and plant products and greater nutritive value of food crops.

Environmental Conservation: Research into the ecology of plant compounds mediating defense against pathogens and pests, particularly invasive species. Areas of interest include, but are not limited to, the mechanisms, ecology, and conservation consequences of bioactive compounds influencing resistance to invasion or the success of management efforts to control invasive species. Research should incorporate cutting-edge technologies to address questions grounded within a conservation framework.

Strengths of Plant Biology at UMass

1) Research and Scholarship

A strength of plant research and scholarship at UMass is that faculty expertise spans molecular to ecosystem processes (*see attached summary of faculty research and funding*). Specific areas of strength are:

- Plant, soil, and ecosystem health (SSA, BMB, ECO)
- Genomics, evolution and biodiversity (BIO, BMB, ECO)
- Cellular, developmental and genetic mechanisms (Biology, BMB, SSA)
- Local food production and integrated food and farming systems (SSA)
- Sustainable agriculture, /landscapes and /forests (SSA, ECO, BIO)

2) The Plant Biology (PB) Interdepartmental Graduate Program

PB has a number of important strengths that reflect a strong culture of plant biology on campus:

- Breadth of the program – both in departments and disciplines
- Cohesive cohort of students and a strong PB program culture
- Labs are collegial and afford opportunities for excellent student interactions
- PB provides good support for junior faculty members in the form of student funding
- A weekly PB program seminar with speaker lunch for the students
- A highly regarded, fall PB Symposium, nationally and internationally recognized <https://gpls.cns.umass.edu/pb/symposium>
- Potential to link basic and applied plant biology

PB has some limited, small financial instruments for support of students:

- Gilgut Endowment – funds at discretion of Gilgut Professor, usually supports one student
- Some Hatch funds – support of faculty with Hatch projects
- Davis Botany Fund – provides small \$ for student professional development

3) Facilities & Equipment

UMass has a wealth of research and teaching facilities (*see attached summary of facilities*). In most areas these compare favorably with peer institutions, and in the case of recent equipment for biochemical and molecular studies purchased with MLSC funds, these resources exceed those at many peer institutions. New laboratory space in Paige, LSL and soon Morrill are recent enhancements to facilities used by PB faculty.

4) Resource/Learning Centers

- Center for Agriculture and the Environment
- Ag Learning Center
- Water Resource Center
- Diagnostic Laboratories
- Herbarium

5) Development and Support of Agriculture and Horticulture

UMass has a rich history and capacity for applied research and outreach in agriculture and landscape horticulture. Faculty, students and staff work with producers and other stakeholders in Massachusetts, New England, nationally and internationally. The applied agricultural expertise and outreach are unique to UMass among research universities in the Commonwealth and facilitates developing projects with combined research and outreach components. It also provides students interested in production agriculture and sustainable managed landscapes with unique training in applied research.

- Soil health research including cover cropping and bioremediation
- Research soil process related to climate change including biochar and microbial cycling
- Connecting urban populations with local production and producers with ethnic crops
- Programs integrating biointensive pest management on multi-crop, small-scale farms
- Applied and basic plant pathology targeting local to international plant disease problems
- Nationally recognized program in turfgrass

Challenges to Plant Biology at UMass

Many challenges below reflect challenges to CNS as a whole, as discussed in the CNS Strategic Plan.

- 1) Lack of communication and coordination of different efforts in plant biology at UMass
 - Limits interactions/synergism/collaboration between basic and applied research.
 - There is also a **lack of visibility** of efforts/accomplishments across campus.
 - Plant Biology faculty are spread across campus in different departments and widely spaced buildings.

- 2) Staying at the forefront of plant science/agricultural research
 - **Maintaining and strengthening facilities and resources**
 - *Growth chambers*
 - > Controlled environment growth space limiting
 - > Space not adequately coordinated across campus
 - > Chambers in Morrill aging
 - *Laboratories*
 - > Plant biologists in ECO need better laboratory space
 - > Laboratory space for new hires in plant biology needs to be identified
 - > Consolidation of Stockbridge faculty in improved laboratory space near Paige
 - *Farm and field facilities* management is on an ad hoc basis and needs to be evaluated.
 - *Program for steady investment in equipment and data processing capacity.* State-of-the art plant biology research is more and more dependent on expensive equipment and data processing capacity. Investment in such resources/core facilities must sustained for faculty to remain competitive. This holds for all life scientists on campus.
 - **Increasing and retaining plant biology faculty**
 - Pending retirements will impact research and curriculum – aging faculty particularly in SSA and ECO
 - Recent loss of key plant biology faculty member - Schnell
 - New faculty needed to build synergisms particularly between basic and applied
 - **Current challenges of funding research**
 - Low percentage funding rate of federal grants in basic plant science research

3) Training students

- **Graduate and undergraduate curriculum**

- The plant biology curriculum is extensive, but not coordinated across campus (*see Appendix for course offerings*).
- There is no undergraduate major specific to plant biology.
- Curriculum is deficient in a number of major areas, e.g. there is no plant biochemistry course, or course in photosynthesis.
- There are very limited graduate courses in plant biology.
- There are many pending retirements in SSA and ECO that will impact course offerings.
- Current faculty are occupied with undergraduate teaching with limited/no time to contribute to graduate course offerings.

- **Recruiting excellent graduate students**

- Stipend is low compared to peer programs
- First year teaching requirement is prohibitive to recruiting
- Limited fellowships and no training grants

4) Serving the local agricultural community

Close collaboration between Land Grant University faculty and Extension professionals has long been a hallmark of successful agricultural and horticultural outreach in the U.S. and in Massachusetts. Several factors have combined in recent years to weaken that collaboration.

- Lack of communication between Extension professionals and UMass faculty in the plant sciences
- Little Extension-style outreach in departments outside the legacy Land Grant departments, e.g. SSA, ECO, Nutrition
- Academic recognition of applied outreach work hindered by inadequate annual reporting forms, definition of scholarly activity largely as research and teaching on campus.
- No available database for faculty to search for colleagues with expertise to aid in directing community members to the right source for information.

Mechanisms to Address the Challenges to UMass Plant Sciences

The following summarizes the committee's recommendations for enhancing plant science research and teaching and "Bridging the Divide" between basic and applied disciplines. *Many of these recommendations mirror recommendations in the CNS strategic plan.*

- 1) Create a PLANT SCIENCES CONSTORIUM on campus!
The committee recommends as a model the Interdisciplinary Plant Group at the University of Columbia, Missouri. <http://ipg.missouri.edu/about.cfm>
This could be a revenue neutral or minimal investment effort to bring all the plant sciences under one umbrella and website at UMass. This site could be a clearing house for everything plant related, basic and applied on campus.
- 2) Develop a Plant Sciences Steering Committee to advise the CNS Dean and interact with CAFÉ (revenue neutral)
- 3) Develop strategic faculty hiring plan (*See attached documents – Current Faculty & Hiring recommendations*)
- 4) Provide centrally funded competitive grants as incentives for interdisciplinary collaborations to collect data to obtain federal funding. Grants sufficient to support personnel (either one graduate student, one tech, or one postdoc) for one year, with possible renewal for one year, plus supply funds (Investment).
- 5) Small "Planning" grants (2 to 5K) directed specifically to collaborations between Extension and Research faculty to hold workshops, host a seminar speaker or otherwise begin to develop a partnership (Investment).
- 6) Strengthening the Plant Biology Interdepartmental Graduate Program
 - **Immediate "Revenue Neutral" activities**
 - Continue Plant Biology Symposium inviting and encouraging broader participation in designing the symposium by all members of PB.
 - Hold PB faculty meetings once a semester to update and engage faculty in program activities and challenges.
 - Have joint seminars between PB and SSA, with one for each program shared each semester.
 - Engage faculty more actively in the Fall PB graduate Core I course, arranging participants in the previous Spring and meeting as a group to discuss content and expectations.
 - Continue December Holiday party "Yankee Swap" with effort to broaden faculty participation.
 - Ensure all new faculty in Plant Biology disciplines are welcomed to the program.
 - Keep website up to date with program activities and members accomplishments
 - Produce electronic newsletter once per semester (minimum), link to website and distribute program members and to administrators.
 - Improve tracking of PB alumni and invite back to campus as appropriate.
 - Arrange to send newsletter to alumni of the program.

- Bring faculty from small colleges to campus in our seminar series in the fall to showcase our program and potentially enhance recruitment of good students from those colleges.
 - Link PB calendar of activities and SSA seminar calendar to the CAFÉ website.
 - **“Immediate” activities requiring some time planning and new monetary investment or reallocations**
 - Arrange additional social/educational events utilizing orchard and farm facilities, e.g. Fall: pick your own apples at Cold Spring Orchard combined with talks about apple growing, pathogens, market, etc. Spring: Barbeque at Turf farm, agronomy farms, with an hour of talks by students or others on this aspect of plant science. Talks should include example of applied and basic research. All PB students expected to attend. Possible funding through CAFÉ.
 - **Efforts requiring more time and likely moderate financial investment**
 - Coordination of certain common curricular needs with other IDGPs. Important components:
 - > Computer literacy
 - > Statistics and experimental design
 - > Grant/proposal writing.
 - Taylor curriculum better for diversity of students in the PB graduate program, while also offering more advanced training.
 - > “Modular” courses, four weeks long (one credit) on different advanced topics with students able to choose to take one to three in any one semester.
 - > Develop more breadth in current requirements
 - Develop short methods courses – held over winter break or summer sessions:
 - > Microscopy
 - > Genomics
 - > Mass spectrometry
 - > Intro to plant taxonomy/phylogenetics
 - **Efforts requiring considerable time and or financial resources**
 - Increase base stipend to be competitive with peers
 - Ensure all first year students can be supported on a fellowship for AT LEAST the first semester
 - Develop training grant program for application to federal agency
 - Hire more faculty with interests spanning basic to applied!!!
- 7) Evaluate and coordinate undergraduate Plant Biology curriculum
SSA, Biology, ECO, Microbiology and potentially Food Science all offer courses relevant to plant science. (*See attached course summary*). These courses need to be coordinated within the overall evaluation of CNS curriculum. The location of UMass in the heart of a sustainable agriculture “movement” in the Pioneer Valley provides students with easy access to some of the most progressive farms and marketing businesses in the U.S. This allows students access to internship and applied research opportunities. Undergraduates need to be engaged more formally in research at UMass field facilities and farms, and opportunities for courses and research during the summer need to be

developed. International opportunities in the plant sciences for undergraduates should also be expanded.

- **Present curriculum**

- Enrollment and course content should be evaluated for overlap, and possible enhancement or sequencing.
- Identify the major strengths of the curriculum.
- Identify key holes in the curriculum
- Explore possible creation of a concentration in Plant Biology.

- **New opportunities**

- Need to consider offerings in context of pending retirements
- Develop more opportunities for “authentic” research and field experience in plant sciences for undergraduates
 - > Ex. - Bartlett and Seidler course on plant diversity using greenhouse collection
 - > Ex. - Bezanilla Cell and Molecular Biology lab course using microscopy and modern recombination cloning methods to study organelle targeting in plant cells
 - > ICONS module using Plant Cell Culture Collection
 - > Reactivate the course in plant tissue culture
 - > Increase structured experiential opportunities such as the award-winning Turf Club and the very popular Student Farm and Market
- Develop a meaningful “Career Fair” to highlight opportunities in Ag Biotech, Ag Industries and other industries related to plant biology to attract students to the field.
- Develop more international opportunities for semesters abroad or short courses, such as the Mangan’s “Food Systems in Cuba”
- Build existing internship programs with industry for undergrads, based on the successful AS program in SSA

8) Develop at “Ag Tour” of MA agriculture for plant science related faculty members (Investment required)

Based on AG tours at other land grant universities. One or more day bus trip to different ag facilities (from growers to processors) in the state. Led by CAFÉ and attended by CNS dean or other administrators.