# Academic Plan

**Department of Plant Pathology**
**January, 2008**

## I. Introduction

Plant pathology is an integrative discipline that seeks to develop a comprehensive understanding of plant-microbe interactions. Research in plant pathology ranges from fundamental studies that advance science in a general way to more mission-oriented research intended to generate the knowledge needed to manage diseases affecting the health and productivity of plants in agricultural and native ecosystems. The problems confronted by plant pathologists are dynamic owing to the continual emergence of new diseases and increasingly restrictive environmental and food safety regulations. In the face of these constraints, agriculture must produce more on less land, using less water and less energy in order to remain competitive in the global economy. The Department of Plant Pathology is dedicated to meeting these demands through the efforts of its faculty, which presently consists of 16 Academic Senate members, four Cooperative Extension (CE) Specialists (three of these are split appointments) and two AES Plant Pathologists (totaling 6.63 I&R, 9.64 OR and 2.85 CE FTE). Additionally, the department houses seven Emeritus faculty and five USDA Scientists (two are recent hires expected to be in residence by July 1, 2008). Each of the USDA scientists holds a WOS lecturer appointment, functions as a member of our department, and is an integral element of our academic programs.

## II. Vision

The Plant Pathology Department strives to be the premier source of discovery and application of knowledge related to plant-microbe interactions and thereby to facilitate development of innovative and durable solutions to the management of plant diseases. This vision will be realized by: 1) maintaining a broad portfolio of fundamental and mission-oriented research characterized by creative, cutting-edge and integrated approaches to understanding host-parasite interactions at all organizational levels, 2) providing a stimulating and supportive environment for graduate students and post-doctoral scholars, and 3) sustaining effective extension, outreach, and public service programs.

## III. Missions

Faculty members in the Department of Plant Pathology represent a diverse array of expertise in research that spans organizational levels from molecular mechanisms to interactions among organisms and populations. The knowledge generated in research is applied to our mission within the Agricultural Experiment Station: Development and implementation of innovative, effective, and environmentally-responsible disease management practices. Closely coupled to all these activities is the training of graduate students, who are key contributors to our research programs and future leaders in a field that will be critical to our capacity to produce a safe and reliable food supply for a growing global population.

Owing to the success of our faculty and students, the Department of Plant Pathology has earned a reputation as a world leader in its research, graduate training and extension programs. We aim to sustain and enhance this reputation through the energetic pursuit of our academic missions, which are embodied in following key objectives:

- To discover and elucidate mechanisms in host-pathogen interactions that are critical for disease development and that can be exploited to mitigate disease impacts.
- To discover and elucidate the biochemistry, genetics, life history and ecology of microorganisms that cause plant diseases and environmental factors that influence their activity and success.
- To foster the intellectual and professional development of students and postdoctoral scholars so they can realize their potential as scientists and thus contribute to the advancement of our discipline throughout their careers.
- To expand the scope and quality of our undergraduate teaching endeavors through offerings within our areas of expertise (e.g., plant pathology, mycology, bacteriology virology, genomics, bioinformatics and plant-microbial ecology) and participation in courses that relate our science to issues of importance to society.
- To contribute to the continuing education of our stakeholders by helping them to access the most current and accurate information available for resolution of problems affecting both native and managed ecosystems.
- To increase the scientific literacy of the general public and the science-based information available to educators, regulators and policy-makers.

## IV. Research Programs

Research in plant pathology requires expertise in the subjects of mycology, virology, bacteriology, genetics, molecular biology and biochemistry, epidemiology, and ecology. Plant pathology integrates information and methodologies from these diverse biological disciplines to discover basic knowledge about the interactions of microorganisms with plants (as individuals and as populations) and environmental factors that result in plant disease or resistance. Thus, the aforementioned subjects constitute core competencies of the Department of Plant Pathology, and represent the means by which the department has and will continue to make fundamental contributions to the life sciences, provide advances in the etiology, diagnosis and management of plant diseases, and assure the sustainability of agricultural and natural ecosystems. These core competencies form the foundation for the Graduate Program in Plant Pathology, and enable us to train future generations of scientists, educators, researchers and practitioners.

Aside from fundamental and practical significance in their own right, our research programs also connect in significant, supportive roles to other important campus, state, and national programs, such as the Foundation Plant Services, the Foundation Seed Service, the California Department of Food and Agriculture, the National Plant Diagnostic Network, the Contained Research Facility, the Plant Genomics Program, and the Genomics Center, to name a few.

### A) Research Thrusts and Areas of Excellence:

Our department has consistently ranked as the top department or among the top departments of plant pathology in the United States. This is due in part to the quality and impact of our research programs. Within our department, there are four broad research thrusts represented by faculty members who have received numerous national and international awards for their accomplishments. These thrusts are integrated, with areas of overlap, and provide a continuum of basic and translational research as follows:

**Microbial Biology of the Phytosphere**: Fundamental to the productivity and sustainability of both managed and natural ecosystems is an understanding of the ecology and biology of microbes in association with plants. During their interaction with host plants pathogens must operate within a community of microorganisms. Microbial biology of the phytosphere encompasses the study of microbial populations and communities associated with plants and their interactions with their physico-chemical environments. These associations include parasitic and non-parasitic interactions, including endophytic relationships. The complexity of these communities, their population dynamics, and pathways for communication and signaling among the members of the community are poorly understood. New, effective and environmentally sound approaches for controlling plant diseases will increasingly rely on a heightened awareness of the microbial interactions that influence the activities of pathogenic, commensal, and mutualistic microorganisms in the phytosphere and surrounding environment. Culturable microorganisms represent but a small fraction of the microbial diversity present in the phytosphere, and our ability to understand non-culturable organisms is in its infancy. Metagenomics and associated enabling technologies allow us to advance the objective of fully characterizing the microbial diversity of the phytosphere. Comparative gene studies and expression experiments involving transcriptomics, proteomics, and metabolomics will help piece together metabolic networks relevant to microbial pathogen development and disease. For example, unresolved are the cues that trigger or contribute to developmental transitions of microorganisms from quiescent, endophytic associations to invasive and pathogenic states. Resolution of these issues will require a more complete characterization of the biology and chemistry of initial sites for microbial establishment, development and infection, and the metabolic responses of pathogens and plants to changes in these microenvironments. State-of-the-art technologies are enabling biologists to probe and visualize inter-organismal interactions with resolution and specificity unimaginable just a few years ago. Thus, microbial biology of the phytosphere is highly interdisciplinary, incorporating traditional methodologies (advanced microscopy, biochemistry, molecular biology) and innovative technologies (e.g., sensitive bioreporter systems, metagenomics) to address fundamental and practical issues related to microbial ecology. Our programs here must continue to be sufficiently robust and integrated so as to maintain relevance to the diversity of agro-, natural and disturbed ecosystems.

The Department of Plant Pathology has the largest group of faculty on campus with expertise in the area of phytosphere microbiology. Historically, our department has had particular strength in soil microbiology, at one time with as many as eleven faculty members having research programs emphasizing or involving soil microorganisms. Examples of research foci included microbial community dynamics, population structure of soil-borne microorganisms, genomics of root-microbe interactions, *Phytophthora* biology and genomics, and the effects of environment (including cropping practices and irrigation) on microbe biology and host resistance. Past retirements and resignations and anticipated retirements during the next five years will create opportunities for strengthening and invigorating programs in rhizosphere biology.

The addition of new faculty with programmatic foci on plant-bacterial interactions (Coaker) and microbial ecology (Leveau) is representative of our department's commitment to bring contemporary methods and fresh insights for achieving our goals. However, continued investment in this area will be critical to capitalize fully on advances in microbial ecology and to build the intellectual depth required to interpret the significance of the increasingly complex data sets acquired in comprehensive analyses of the phytosphere.

**Faculty:** Bostock, Coaker, Cook, Davis, Epstein, Gordon, Gubler, Leveau (2008), MacDonald, Michailides, Rizzo, and Subbarao. Relevant expertise is also provided through our USDA colleagues: Baumgartner, Browne, and Kluepfel.

**Genetic Structure of Microbe and Plant Populations:** Studies of host and pathogen population structure are a critical component of both applied and basic research in plant pathology. Such studies have direct implications for epidemiological research, for example by characterizing the migration and mixture of pathogen genotypes, and providing insight into the role of host and pathogen genotypes in the rate of disease increase in the field. They also have the potential to contribute to our understanding of long-standing issues in plant pathology, such as the nature of selection and rate of evolution in host and pathogen populations; co-evolution of the pathogen and host; quantifying the distinctiveness of pathogen populations; and helping resolve the classification of subspecies and species of microorganisms. Studies of host plant diversity and genetics of disease resistance can also provide a foundation for genetic linkage analysis of trait-marker associations (e.g., disease resistance), leading to tools for plant breeding through marker-assisted selection and ultimately to the cloning of genes that underlie disease resistance phenotypes.

Research by faculty in the department of plant pathology contributes towards understanding the ecology, evolution, and systematics of a range of pathogens, including viruses (Falk, Gilbertson, Rowhani), prokaryotes (Gilbertson, Kirkpatrick, Coaker, Leveau), fungi and Oomycetes (Davis, Gordon, Gubler, Rizzo, Van Alfen). Faculty research programs also contribute in significant ways towards understanding the evolution and diversity of host species, with a particular emphasis on genes implicated in innate immunity and race-specific resistance (Bruening, Coaker, Cook, Ronald, Gilchrist). This will continue to be an important area of research for many of our faculty, and such studies will involve a wide range of pathogens and a variety of experimental approaches. However, this area of research will benefit from new genomics methodologies, in particular recent advances in high throughput genotyping and sequencing. Thus, future studies will employ new methods and provide greater insight into the genetic relationships among pathogens and their hosts for the purpose of revealing new targets and approaches for disease resistance. Knowledge generated from such studies also could be applied to disease forecasting schemes that involve monitoring and prediction of the destructive potential of new pathogen genotypes; chemical and biological control strategies could be tailored to particular pathogen populations; and the potential to use species and ecosystem diversity as a tool for sustainable agriculture could be explored with renewed precision. In many ways this represents a convergence of the fields of plant and pathogen genetics, genomics and epidemiology.

Looking forward, one of the grand challenges for the discipline of plant pathology is to define genes and associated genetic variation that underlie the functional properties of host and pathogen populations. With the advent of genomic tools, the traditionally separate fields of population biology, genomics/bioinformatics, and forward genetic studies of gene function are becoming integrated. This convergence is most evident in the field of human genetics, but similar opportunities exist in the area of plant pathology. Thus, with sufficiently well characterized genomes and adequate knowledge of allelic and phenotypic variation, it is possible to study gene function in the context of populations. The term “population genomics” has been used to describe this emerging area of science. Concepts that incorporate quantitative theory, temporal and spatial relationships, genetic drift, iterative cycles of variation and selection, major gene effects, and novel gene interactions, are

imbedded within this changing view of molecular biology. This type of information provides the potential to identify and validate candidate genes and gene interactions that confer adaptive variation to host or pathogen. However, to effectively utilize the resulting data sets will require new statistical tools and revised theory. Thus, population genomics is an area that is ripe for academic pursuit. A key challenge will be to integrate and apply this new approach to plant pathology problems and to take the lead in applying these approaches to entire microbial ecosystems. Thus, this area can be well-integrated with programs related to the microbial biology of the phytosphere. The potential outcome of such studies is an improved understanding of disease development and novel approaches to manage the disease ecosystem, and plant pathology should be well positioned to demonstrate the utility of this improved understanding. Clearly, a move into the area of 'population genomics' will require hiring new faculty, training a new generation of students, and re-training existing faculty.

**Faculty:** Coaker, Cook, Davis, Falk, Gilbertson, Gilchrist, Gordon, Gubler, Kirkpatrick, Leveau (2008), Michailides, Rizzo, Ronald, Subbarao, and Van Alfen.

**Cellular and Molecular Mechanisms of Plant-Microbe Interactions:** Comprehensive understanding of the mechanisms plants use to defend themselves and the mechanisms pathogens use to disable plant defense responses or manipulate host mechanisms for self destruction can lead to the development of novel synthetic approaches to disease resistance that may ultimately prove far more durable than major genes for resistance have historically proven to be. Durable synthetic resistance could be achieved through the genetic modification of plants to extend their metabolic capacity (e.g., novel enzyme engineering). Engineering plants to resist microbes by incorporating novel disease control strategies not normally encountered by microbes should enable strong and durable disease control. Genetic modification to improve biological control agents, which may include endophytic microbes, is also a strategy that has promise.

The Department of Plant Pathology has an exceptionally strong group of faculty focused on dissecting and understanding the interactions of plants with viruses, bacteria, oomycetes and fungi. Our faculty employs diverse approaches to facilitate a mechanistic understanding of microbial pathogenesis and plant disease resistance. Interactions are studied at multiple levels, and include cellular, physiological and biochemical, molecular, and genetic, and recently at the more comprehensive levels of genomics, proteomics, and metabolomics. Significant advances have been made by our faculty in elucidating resistance gene architecture (Bruening, Cook, Ronald), in addition to contributing towards a mechanistic comprehension of bacterial and fungal pathogenesis (Bostock, Coaker, Gilchrist, Ronald). Additional faculty members have made seminal discoveries in viral host-vector interactions as well as the molecular basis of resistance and susceptibility (Bostock, Bruening, Coaker, Falk, Gilbertson, Gilchrist, Kirkpatrick, Ronald). Furthermore, multiple faculty members are actively involved in studying both fundamental and applied aspects of the plant defense response. The research strength of this group is further enhanced by interactions with faculty from the departments of Plant Sciences (Dandekar, Michelmore, Phillips, St. Clair, Suslow), Entomology (Hammock, Ullman), Nematology (Williamson) and Plant Biology (Dehesh, Lucas) who are studying molecular plant-microbe interactions.

During the next five years, anticipated retirements in this area will provide opportunities to strengthen our existing programs. Sustained investment in this field using contemporary genomic, proteomic, and molecular techniques will be necessary to elucidate mechanisms

controlling plant-microbe interactions and exploit these mechanisms to develop novel, synthetic disease resistance strategies.

**Faculty:** Bostock, Bruening, Cook, Coaker, Epstein, Falk, Gilbertson, Gilchrist, Kirkpatrick, Ronald, and Van Alfen.

**Integrated Approaches to Disease Management:** The three research thrusts described above will provide new and important fundamental knowledge that can be translated into effective, novel, and environmentally sound approaches to manage plant diseases. California's preeminence in U.S. and world agriculture, the diversity of our production systems, and the health and conservation of our natural ecosystems are all contingent on plant health. Thus, plant pathology and allied disciplines play a central role in the stewardship of these resources. Knowledge of plant pathogens and factors that influence disease development is an ever-present need, as changes in plant production-related technologies constantly alter plant populations and microclimates. Climate change and competition for limiting resources (e.g., water) also will have new and important consequences, necessitating the development of new strategies that must encompass all aspects of plant health. We are already witnessing a consequence of globalization and increased trade and travel with interceptions and introductions of exotic and potentially invasive pathogens increasing at an alarming rate. This coupled with rapid population growth and the associated changes in land-use patterns will bring to bear a diversity of interacting stressors that will challenge our ability to maintain California's vibrant agricultural economy and the aesthetic and recreational values of our natural and urban landscapes.

The identification of plant pathogens and control of the diseases they cause has long been a primary goal of plant pathologists. The most effective and environmentally-sound disease management strategies will be developed from a thorough, fundamental knowledge of plant pathogens and how they interact with their plant hosts, with each other, with vectors, and with the environment—including specific conditions that promote or are conducive for disease development. Thus, within this research thrust diverse efforts on many plant pathogens contribute to the common goal: gaining knowledge that can be used for developing integrated, environmentally responsible approaches to manage plant diseases. The Department currently has well-recognized research expertise across all groups of microbial plant pathogens (prokaryotes, fungi, oomycetes, and viruses). Furthermore, our programs are enhanced by our close connections and history of collaboration with faculty in the Departments of Nematology, Entomology, and Plant Sciences. It should be noted, however, that several retirements have weakened our programs in a number of areas, such as host:pathogen genetics, epidemiology and rhizosphere biology. Potential retirements during the next five years also will affect programs in virus diseases and diseases of important perennial crops such as grapes.

Our faculty utilizes contemporary technologies in efforts to determine the etiology of plant diseases and to develop appropriate disease management strategies. It is imperative that core efforts in disease management will continue, but with the incorporation of innovative technologies, informed in part by research described above in the preceding thrust areas. For example, advances in detection and remote sensing will further refine our understanding of the current context within which disease occurs. This knowledge will enhance predictive capabilities to tailor management to meet local or regional needs. Advances in rapid diagnostics, coupled with epidemiological tools to image the pattern and spread of disease outbreaks will inform regulators, growers and other stakeholders where and when to deploy

resources to contain and manage an outbreak. Our understanding of plant and pathogen genomes has advanced remarkably, especially in relation to the structures and functions of disease resistance genes and pathogen effectors. It will be important for plant pathologists to apply this information in the field for disease management. While application of these strategies will likely contribute to more efficient crop production, history demonstrates that new diseases will continue to emerge and old problems will re-emerge. Thus, continued investment to maintain our traditional strengths in the biology of plant pathogens will enable us to meet these challenges. Given the importance of California's position in global trade, we must be prepared to serve as a primary resource for the state and nation for basic information about introduced pathogens that threaten agriculture and natural systems. This will require a continuing commitment to develop and test diagnostic tools and to be informed of the status of diseases in the field. The Department of Plant Pathology is uniquely positioned to provide the essential interface with scientists in other disciplines including plant breeding, plant biotechnology and agricultural engineering to take multi-disciplinary approaches to manage current and future plant disease problems.

**Faculty:** Bostock, Coaker, Davis, Epstein, Falk, Gilbertson, Golino, Gordon, Gubler, Kirkpatrick, Leveau (2008), MacDonald, Michailides, Rizzo, Rowhani, and Subbarao. Expertise is also provided through our USDA colleagues, Baumgartner, Browne, and Kluepfel.

**B) Maintaining Excellence into the Future:**

Current staffing levels correspond very closely to the I&R and OR targets established for the Department of Plant Pathology by the CA&ES. Thus we anticipate recruiting a new faculty member (50% I&R and 50% OR) for each retirement or separation that occurs over the planning window (to the end of the 2012-13 academic year). During this interval, four faculty members will reach age 65 or older (Bruening, Gilchrist, Gubler, and Van Alfen). Each plays an important role in one or more of the departmental areas of excellence and, if the retirement option is exercised, their departures would create critical programmatic gaps. An Academic Federation member of our department (Rowhani) also will reach age 65 within the planning window. This individual contributes significantly to our programmatic mission by providing innovation in plant virus etiology and detection and critical support to the FPS. Strategies for addressing potential vacancies and assuring sustained programmatic strength are described in a following section.

**C) Opportunities to Build on Strengths:**

The combination of contemporary and newly developing technologies, coupled with the research areas of excellence within our department and the emerging research directions for our college and campus, identify key areas for programmatic growth. These growth areas have the potential for synergistic benefit to basic plant pathology and to the current and future needs of California. The areas have been identified for recruitment are as follows (note the order does not necessarily reflect relative priorities) and each is described more fully below.

1) **Plant Virology**

2) **Integrated Strategies for development and implementation of Disease Resistance**

3) **Functional genomics and proteomics in plant-fungal interactions**

## 4) Epidemiology and disease ecology

### 1) Virologist, virus-plant interactions.

Among the major pathogen groups, viruses may be considered to be the most damaging of plant disease agents. Viruses cause serious plant diseases in California, and a number of injurious viral diseases have been introduced into California recently. Plant viruses also provide elegant tools for studying plant biology and for expressing foreign proteins in plants. Our department has been taking the lead in teaching not only plant virology but also general virology courses on the campus. Given an impending retirement in this area, it is critical that the department recruit a virologist to its faculty to meet both research and teaching responsibilities. Recent discoveries and new technologies have made it possible to investigate the underlying mechanisms of virus replication, movement in the plant, vector transmission, and symptom-induction. Viruses have been demonstrated to alter host plant gene expression and the accumulation and organelle targeting of host proteins, and underlying mechanisms involving host micro RNAs and protein-protein interactions, among others, have been partially elucidated. However, progress to date would seem to have just scratched the surface of what can be investigated and exploited in efforts to mitigate plant virus disease and disease-related symptoms. We are proposing to recruit a new member of the Plant Pathology faculty to develop a program emphasizing molecular and/or genomics aspects virus-mediated alterations of the host plant with the mission of understanding and controlling disease. This proposed program would complement and likely would be synergistic with continuing research in the department on plant genomics and on virus gene expression and replication, movement in the plant, vector transmission, and etiology and epidemiology, as well as applications of viruses in biotechnology. The appointee would be expected to contribute to teaching courses in virology and other areas of expertise. This position would maintain a key area of excellence in our Department and would co contribute to the teaching responsibilities in virology for the College and campus.

### 2) Integrated Strategies for Disease Resistance

Host resistance is the most economically and environmentally desirable means of disease management. Despite this fact, less sustainable approaches, such as chemical control, often dominate agricultural practices, either because suitable sources of resistance have not been identified or because they have not been introgressed into desirable cultivated materials. We anticipate that the need for disease resistant varieties will continue to increase in the coming decades, especially as production systems change to promote increased sustainability, or to accommodate changing climatic conditions, or to satisfy consumer demand for specialty and organic products. To meet these needs, we must better understand and utilize natural genetic sources of disease resistance, and, where appropriate, engineer novel pathways for disease resistance. Thus, despite significant advances in our understanding of pathogen and host genes involved in disease resistance, there are still large gaps in our knowledge, and these gaps limit our ability to harness the full genetic potential of individual plant species.

We envision development of a faculty position that is focused on filling some of these knowledge gaps, and formulating more rational and systematic approaches to plant disease resistance. On the basic level, this may involve genomic approaches to catalog diversity and characterize the function of disease resistance genes at the level of plant populations, discerning the principles that govern the selection and success of particular resistance gene variants among thousands of possibilities, elucidating signal transduction pathways and the nature and relevance interacting proteins, etc. On the applied level, the successful applicant

would utilize understanding gained from basic studies to develop improved strategies for disease resistance. Research topics might include manipulation of natural variation through molecular breeding and plant transformation, or engineering novel interventions into pre-existing genetic pathways for disease resistance. While research efforts could focus upon single gene resistance, it is hoped the successful candidate also would consider investigation of polygenic and/or non-host resistance, areas that have received less attention but that have considerable potential. Although the successful candidate may make use of model systems, it is expected that emphasis would be placed on an economically important crop(s) and their wild relatives, in particular those with relevance to California agriculture. Thus, successful applicant would be expected to develop an innovative research program that would be competitive for external research funding, which could include federal, commodity and industry funds. The successful applicant would also be expected to be involved in teaching undergraduate and graduate level courses, which would reflect the candidate's area of specialization and the needs of the Department.

**3) Functional genomics and proteomics in plant-fungal interactions**

We propose a position in the area of functional genomics of plant-fungal/Oomycete interactions. This position will capitalize on the revolution in biology being driven by rapid advances in genetic technologies and high-throughput functional analyses. These technologies are creating massive amounts of primary sequence information and analytical tools that address a wide diversity of fungal and Oomycete pathogens and their host plants. A challenge for the future is to utilize these data and tools to uncover fundamental principles that underlie fungal/Oomycete pathogenesis and disease. Ultimately we desire a level of understanding that is sufficient to predict the outcome of any given plant-microbe encounter, and with this knowledge to design effective intervention strategies.

The UC Davis department of plant pathology provides an opportune environment in which a young faculty member could pursue these goals. Collectively our faculty explore a range of plant-fungal interactions that are important to California, often at the population and organismal level, but we lack expertise to explore fungal biology from a system or genome-wide perspective. We envision potential synergy with current faculty efforts to understand the molecular basis of fungal and/or Oomycete virulence, pathogenicity, host range, vector association, survival and dispersal, and other processes. For example, comparative genomic studies among bacteria, fungi and Oomycetes—organisms from different kingdoms that exhibit the common ability to cause plant disease—will help identify functionally conserved genes that are required for pathogenicity. Genomic technologies also have great potential to characterize plant responses to pathogen infection and thus to elucidate processes that govern host resistance, susceptibility, tolerance and symptom expression. From a practical perspective, these technologies enable the rapid detection and discrimination of pathogen genotypes with unprecedented resolution, they enhance our capacity to explore the ecology and evolution of pathogens and their hosts, and ultimately they will lead to new and/or improved strategies for plant disease control.

Adding faculty with expertise in this area builds logically upon our department's strengths in mycology. This position also fits well within several research thrusts and interfaces exceptionally well with campus and College priorities. Fungal pathogens have complex life histories and diverse parasitic associations with host plants. Thus, management of fungal diseases presents substantial challenges as well as opportunities for targeting and deploying multiple strategies. Our department historically has had great depth in mycology and in the management of fungal diseases. However, resignations during the previous planning period and potential retirements

require that we reinvest in this area. Thus, the proposed position would bring crucial expertise into already strong clusters and thus enable our department to maintain and strengthen its status as a world center for developing novel insights into plant-fungal interactions. This position could be filled through reinvestment in one of the retirements occurring in the future.

**4) Epidemiology and disease ecology**

The impact of plant diseases is determined by the interaction of a pathogen and its host plant, in the context of the environmental conditions under which the interaction occurs. Traditionally, plant pathologists have approached these problems from discrete disciplinary perspectives emphasizing, for example, environmental influences, host-pathogen genetics or quantitative epidemiology. Recent technological advances impinging on all these areas of study suggest that a much more integrated approach is now possible. For example, high throughput SNP genotyping and gigabase sequencing provide opportunities to characterize pathogen evolution at the genome scale. Such technologies can link genotype and phenotype without need for traditional linkage analysis, because historical recombination and allele frequencies can be exploited to identify pathogen adaptations to host genotype and environmental conditions. Likewise our capacity to acquire and process information on environmental parameters has expanded dramatically in recent years. This includes landscape level analyses that draw on satellite imagery, and the application of nanotechnology to monitor conditions on a scale relevant to plant-microbe and microbe-microbe interactions. The convergence of these technologies presents the opportunity to more fully explore the ecological dimensions of plant disease and, in doing so, to contribute to a new paradigm in plant disease epidemiology. The outcome of such investigations will be new insights into phenomena that dictate the success or failure of particular pathogen and host genotypes, and ultimately to increase the efficacy of strategies to manage plant disease. To fully exploit these possibilities requires development and use of appropriate computational approaches to model the behavior of the complex systems under study. The importance of these endeavors is enhanced by the realities of a changing climate and the need to anticipate how this will affect the activity of plant pathogens in both native and managed ecosystems.

To capitalize on these opportunities we are proposing a position in the quantitative ecology and epidemiology of plant diseases. An individual with expertise in this area would help to fill a critical gap in our research and teaching programs, and would complement the skills and research foci of our current faculty. Thus, we could anticipate productive interactions with those using genomic and proteomic approaches to understand the genetic and biochemical bases for resistance and susceptibility, and also with faculty members actively engaged in the study of the epidemiological parameters that must be considered to develop effective disease management strategies.

## V. Teaching Programs

The Department of Plant Pathology is the administrative home of the Graduate Program in Plant Pathology, which offers programs of study leading to M.S. and Ph.D. degrees, and of the Science and Society Program, which offers an undergraduate minor. Members of our faculty, including Cooperative Extension faculty, also serve as instructors in courses of several other undergraduate and graduate programs, including the Biological Sciences undergraduate major and Biotechnology undergraduate major and graduate programs in Genetics, Microbiology and Viticulture and Enology. Plant Pathology has become the center for research and teaching of mycology on the UC Davis campus. We are committed to the further development of this

specialization. Plant Pathology faculty members also contribute substantially to virology instruction, which includes participation in Microbiology courses 162 and 262.

**A) Graduate education**

The discipline of plant pathology aims to understand and mitigate plant disease as it arises out of the interaction of microbe, plant and the environment. The science and practice of plant pathology draw increasingly on advances in the underlying biological and physical sciences. The principal goal of the Plant Pathology Graduate Program is to prepare students for their careers by providing broad based training in Plant Pathology and in germane allied disciplines.

The Graduate Program in Plant Pathology includes all faculty affiliated with the Department of Plant Pathology or with the Department of Nematology. Currently, the Program also has three faculty members from the Department of Plant Sciences (Labavitch, Michelmore and Suslow) and one from Entomology (Ullman).

Recent and planned modifications to the graduate curriculum have been influenced by results from surveys of Plant Pathology departments and industry and government employers of plant pathologists with graduate degrees in the 2004-2007 period. Most of the results of these surveys, as well as tabulations of graduate degrees by the US National Science Foundation and the National Opinion Research Center, have been incorporated into the report of the American Phytopathological Society (APS) *Ad Hoc* Committee on the Future Education of Plant Pathologists (http://www.apsnet.org/members/com/cmtes_memdetail.cfm?Code=FEPP), which was chaired by Prof. James D. MacDonald of this department. The results show that the Plant Pathology at UC Davis ranks about fifth in number of faculty members. However, no department reported having more graduate students per faculty member, attesting to the health of the UC Davis program. For the US and over a period of four decades, about half of the graduate Plant Pathology degree holders have been employed in academic institutions. However, the proportion employed in government and industry is growing. Of current US PhD candidates, >80% rate employment as a scientist in a government agency as a 3 or 4 on a 0-4 scale, with 4 rating the most favored career path, compared to >70% for employment as a researcher in international agriculture or as a faculty member at a research university. A consistent theme in the responses from industry and government employers is that they find graduates to lack generalized knowledge that industry and consulting work require and that few are classically trained in applied plant pathology, especially in diagnostics and disease management. In addition to the APS and other data mentioned above, guidance on our curriculum has come from surveys of our recent graduates and of other departments on course offerings, as indicated below.

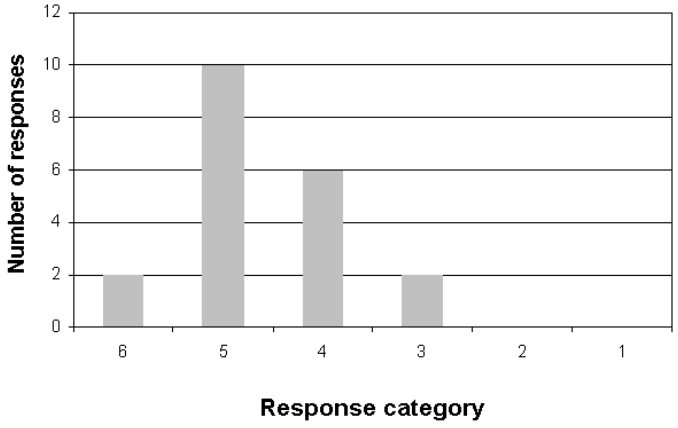
Enrollments of students in the Plant Pathology Graduate Program at UC Davis during the decade that ended five years ago averaged about 35 students each year. New admissions in 2003-2007 have ranged from 6-11 students, with an average of 8 new graduate students each year. Average headcount enrollment was 36 for the 2006 academic year and five graduate degrees were awarded in that year. Faculty members in the Department also supervise about 25 students who are affiliated with other graduate programs, such as Biochemistry and Molecular Biology, Ecology, Genetics, Horticulture, Microbiology, and Plant Biology.

A measure of the success of the Plant Pathology Graduate Program is the positions attained by its MS and PhD graduates. Some students completing the MS continue into a PhD program at

UC Davis or elsewhere, whereas others find technical positions, often in the agricultural services industries, including agricultural biotechnology. Students receiving a PhD. usually accept post-doctoral appointments in university or government laboratories and later secure permanent academic or private sector positions. Many non-U.S. citizens move directly into academic or governmental positions in their home countries. Of 32 students who completed their degree requirements in the Plant Pathology Graduate Program in the 2000-2004 period and whose whereabouts are known, 13 are in postdoctoral positions, 8 have research positions in government or corporate laboratories, 6 are staff scientists or extension agents, 3 have tenure-track faculty positions, and 2 are community college instructors.

For many years, three pathogen-oriented courses (PLP 224, Mycology; PLP 228 Bacteriology; PLP230/230L, Virology), with the option of replacing one of the three with a set of nematology courses, has been central to the graduate curriculum. Some members of the faculty were of the opinion that the curriculum lacked cohesion and generality and was unable to provide assurance that every student in the program would have the opportunity to appreciate the broad sweep of plant pathology. For this reason, development of a new set of two core courses was proposed. We sought feedback from recent graduates of the program as to the value of the education they received from their graduate study in Plant Pathology at UC Davis and the likely worth of the proposed incorporation of core courses into the curriculum. In the first quarter of 2006 we provided recent graduates with a description of changes we were considering, including detailed outlines for two 2-4 hour topics, and asked them to complete and return a survey. Responses indicated satisfaction with the existing program, as indicated by the question and responses given below:

“Overall, I believe that the graduate courses in plant pathology were an important part of my preparation for a career as a researcher in, or practitioner of, plant pathology
1 Disagree strongly
2 Disagree somewhat
3 Neutral
4 Agree somewhat
5 Agree strongly
6 My career is not at a point that will allow me to answer this question”



Nevertheless, graduates were in favor of initiating core courses. For the question indicated below, the responses were 1 for option 1, 5 for option 2, and 10 for option 3.

“Based on your experience with the present Plant Pathology graduate curriculum, do you believe that the proposed core courses and alterations in the pathogen courses and requirements likely would:

1 reduce the effectiveness graduate instruction in plant pathology
2 be equivalent in effectiveness to the present program
3 be more effective in terms of instruction and time invested”

Some remarks by respondents to the survey indicated a desire, similar to that voiced by some members of the faculty, for a curriculum with greater cohesion and attention to the breadth of plant pathology, as well as for instruction in plant disease diagnostics:

“[I]t seems that if we are to be called "plant pathologist", we should at least have some working knowledge, albeit rudimentary, of all aspects of all known pathogens and/or disorders of plants. More importantly, if we are presented with an unknown diseased plant, we ought to be able to make an intelligent conjecture as to at least one hypothetical etiological agent, determine what experiment to conduct to test this hypothesis and the possible results.”

“Can the proposed curriculum ensure that every student who successfully completes his or her degree will have the same basic background and be able to build upon their knowledge in their future careers?”

Therefore, for the 2006-2007-academic year, the Plant Pathology Graduate Program curriculum was revised substantially by offering, as 298 courses, the new two quarter (winter and spring) series “Impacts, Mechanisms and Control of Plant Disease.” These courses take an integrative disease-case-study approach in which plant diseases are examined for their economic and other consequences, disease etiology, pathogen taxonomy, epidemiology and environmental effects, biochemistry, genetics, molecular biology and genomics of pathogen-host interactions, virulence and resistance, and approaches to disease control. The first course emphasizes well studied plant diseases, whereas the second course, in addition, explores less-well-studied emerging diseases and tools for plant pathology research. The two courses are to be regularized as PLP201A, 3 units of lecture and 1 unit of discussion, winter quarter, and PLP201B, 2 units of lecture and 1 unit of discussion, spring quarter.

PLP201A and PLP201B were created to form, together with the fall quarter offering of PLP120, Introduction to Plant Pathology (2 U lecture, 2 U laboratory), a core three-course series that is required of all graduate students in the Plant Pathology Graduate Program. Some students are excused from the PLP120 requirement because they have received related material in other courses, and these students usually complete all or part of their teaching requirement (serving as a teaching assistant in one, and preferably two, courses) in the PLP120 course. The case studies of PLP201AB cover plant diseases caused by bacteria, fungi, nematodes, oomycetes, and viruses and define the information the Program expects all masters and PhD candidates in Plant Pathology to know. A minimum grade of B is required for each of the core courses.

In addition to the core course series, graduate students are required to enroll in

(i) three (two for MS students) of the following four sets of courses

Plant Pathology 224 Pathogenic Fungi (2 U lecture, 2 U laboratory)
Plant Pathology 228 Plant Bacteriology (2 U lecture, 3 U laboratory)
Plant Pathology 230 & 230L Plant Virology (3 U lecture, 2 U laboratory)
Two courses from Nematology 201, 203, 204, 205, and 206 (2 U courses, 204 and 206 have 1 U of laboratory),

(ii) one of two field courses (PLP 205AB or PLP206AB, 4 U total, 2 U of laboratory or field work for each),

(iii) two additional courses, which can be outside of Plant Pathology or Nematology, and

(iv) seminar courses: PLP 290 seminar each quarter and one of PLP 291-295 each year prior to passing the qualifying examination.

Thus, a PhD candidate will take 40-45 units of courses, including 8-11 units of laboratory or field work in 4-5 courses. We conducted a survey of PhD course requirements in the summer of 2007 among the approximately 30 plant pathology graduate programs of the US. Responses were received from 19 programs. For programs on a semester system, units were adjusted (x1.5) so they are directly comparable to the units in the quarter system. One program required no course units for the PhD, and three required 14 or fewer units. Two programs required 15-30 units or 31-60 units, seven required 31-60 units and five required more than 60 units. Accordingly, the UC Davis Plant Pathology Graduate Program unit requirements are close to the average and somewhat above the median for US plant pathology programs.

With regard to laboratory course requirements, eight US programs required 0-1 course, four required 2-3, five required 4, and one required 7. At five laboratory courses, the UC Davis Plant Pathology Graduate Program requirements appear to be more extensive than is typical for US programs.

There is general agreement in the UC Davis Plant Pathology Graduate Program about the value of laboratory courses. However, there is also agreement that the effort expended by faculty members in presenting laboratory courses is significantly under-rewarded by the merit system, and teaching laboratory courses is not regarded as a wise career move. Nor does graduate laboratory instruction benefit the department in assessments of teaching load, given low enrollments and the current administrative emphasis on maximizing student credit hours. For this reason, a sound strategy under the current reward system would be to redeploy faculty resources to high enrollment undergraduate courses to the full extent possible. Furthermore, the expenses of presenting a molecularly oriented wet laboratory course are significantly under-funded by the CAES RAC formula. The provision of teaching assistants also is inadequate. Because of these considerations, there is a developing interest among members of the faculty in dropping some or all laboratory courses.

*Changes and possible changes to the graduate curriculum*. As is indicated above, introducing the core courses 201AB is a substantial and recent alteration in the graduate curriculum. With regard to future changes in the graduate curriculum, changes in several areas are under consideration. Plant Pathology faculty have made substantial contributions to graduate instruction in genomics in the Genetics curriculum. New appointments to the faculty have

enhanced the department's capabilities in genomics, and plans are in progress to offer a course on the genomics, bioinformatics and metagenomics of microbe-eukaryote interactions. This course should serve medical microbiology students as well as plant pathology students. There may be a change in the course requirements listed under Roman numeral (i), above. The Department of Nematology will be considering the development of a new 3U graduate course to integrate material on nematology in a format that would be parallel to the format of the PLP 224, PLP 228 and PLP 230/L courses.

An analysis by the American Phytopathological Society found that there is a significant demand from plant pathology-related industry (e.g., seed and agricultural chemical companies) for MS and PhD graduates who have a working knowledge and skills in two areas: plant disease diagnostics and government regulations and regulatory processes relevant to plant disease management. We are considering returning to a practice of the past: a disease clinic that would require students to examine and initiate a diagnosis of various diseases based on field samples. The disease clinic would be incorporated as a PLP course in the 291-295 series, so that there would be no additional graduate course unit requirement. Cooperative Extension faculty would make important contributions to the disease clinic course.

To address the need for graduates knowledgeable in government regulatory activities (http://www.apsnet.org/members/com/cmtes_annualreport.cfm?id=39&year=2007), the Plant Pathology Graduate Program is considering proposing and initiating a Designated Emphasis in Regulatory Activities (DERA), similar in structure to the current Designated Emphasis in Biotechnology. As is required for all designated emphasis programs, at least one other graduate program (e.g., Food Science, Nutrition, and/or Pharmacology and Toxicology) would be required for the designated emphasis to be recognized by Graduate Division. The DERA would include a course requirement(s) and an internship of several months duration in governmental units such as the USDA Animal and Plant Health Inspection Service or the California Department of Food and Agriculture. Completion of the requirements of the DERA would result in a notation to that effect on the PhD diploma.

**B) Undergraduate education**

The Department's undergraduate courses were designed initially to prepare students for advanced study in the field of plant pathology. Although our courses continue to serve this purpose, they also increasingly contribute to the breadth and specialization needs of other undergraduate majors. For example, Introduction to Plant Pathology (PLP120) constitutes a technical elective for students in the College of Engineering, and satisfies degree requirements for majors in the College of Agriculture and Environmental Sciences (Agricultural Systems and Environment, and Environmental Horticulture and Urban Forestry), and in the College of Letters and Science (Biological Sciences and Plant Biology). Fungal Biotechnology and Biochemistry (PLP130) serves a similar function for majors in CAES and CBS.

Increased faculty participation in undergraduate instruction also has resulted from the development of new undergraduate courses and contributions to programs outside of Plant Pathology, including Microbiology, Plant Biology, Science and Society (SAS), the Freshman Seminar Program and the Davis Honors Challenge Program. Student credit hours taught by Department of Plant Pathology faculty members increased by 67% in 2006-07 compared to 2005-06, which was the greatest fractional increase among CA&ES departments. We anticipate further increases in teaching effort of the department resulting from the addition of two new faculty members, one of whom was hired under the Sustainable Agriculture Initiative and will be a contributor the new major in Sustainable Agriculture. Each of these new appointees is likely to

develop at least one new course. Additional student credit hours likely will also accrue to the department through expanded enrollments in existing courses, as described below.

PLP and SAS courses have contributed significantly to the Department's increased teaching activity in the area of fungal biology. About fifteen years ago, campus offerings in mycology (previously taught in what was then the Botany Department) had dropped to zero. Since that time, the Plant Pathology Department took responsibility for teaching the Introductory Mycology course (now PLP 148) and added new courses in the cultivation of edible mushrooms (PLP 40), and Field Identification of Mushrooms (PLP 135). As a result, the Department is now teaching mycology in these courses and PLP 130, 150 and 185 to about 90 students each academic year. Department faculty members also contribute significantly to undergraduate instruction in virology (MIC162, General Virology, and PLP123, Plant-Virus-Vector Interactions). In total, Department of Plant Pathology faculty members have sole responsibility for, or make significant contributions to, eight upper division courses and thereby help to enhance the breadth and quality of the curriculum available to undergraduates in a diversity of majors.

In 2004, the Department of Plant Pathology took administrative responsibility for the SAS program. This includes the SAS undergraduate minor, the Contemporary Leadership minor and several recently developed programs (Art-Science Fusion, Career Discovery Groups). Plant Pathology faculty participation in lower division general education classes has primarily been through the CAES SAS program and the L&S Integrated Studies Honors Program (8A Special Topics in Natural Sciences and Mathematics and 9, Seminar). Currently nine department faculty members contribute to instruction in three lower division SAS courses: SAS 02 (Feeding the Planet), SAS 20 (Genetics and Society, 3 sections), SAS 30 (Mushrooms, Molds and Society, 3 sections) and to the SAS career discovery groups. Enrollments are currently in the 50-200 student range per course. In some instances, these classes have included honors sections. These courses are well received by students and enrollments have been on an upward trajectory. We expect this trend to continue. For example, SAS 30, which enrolled 100 students per quarter during 2006-07, has 200 students registered for the fall 2007 offering, and SAS 2, which was capped at 70 students last year will likely have 100 students when offered in 2008.

Although the department does not have an undergraduate major, SAS courses may serve as "portal" classes for majors in the College. The idea of portal courses is highlighted in the most recent college academic plan. For example, SAS 02 would serve as a lower division GE complement to the proposed Sustainable Agriculture major. There also remain unfilled instructional needs in SAS in areas to which Plant Pathology faculty members could contribute.

In addition to formal courses of instruction, our faculty has a strong tradition of providing research opportunities to undergraduate students through PLP 199 offerings. Students from many biological science majors gain valuable research experience through this teaching activity, and as our departmental space constraints are relieved, we hope to be able to expand the opportunities to students.

*Possible changes to the undergraduate curriculum*. The Department intends to continue expanding its role in undergraduate education through curricular revisions designed to expand the audience for existing courses, through the development of new courses that apply faculty expertise and interests to campus needs in undergraduate instruction, and perhaps through taking responsibility for existing courses to which Plant Pathology faculty members make significant contributions. The example of the latter is Microbiology 162, General Virology. The department has also been a key contributor to the new CAES program in bioinformatics, which

we expect to continue with the offering of a course on the genomics, bioinformatics and metagenomics of microbe-eukaryote interactions mentioned above.

## VI. Extension Programs

The Plant Pathology Cooperative Extension (CE) programs are organized largely along commodity lines. Also, because we have a CE Specialist at the USDA/UC research facility in Salinas, there is some geographic division of responsibility for improved efficiency. The programs carried out through our department emphasize (1) Tree, Fruit & Vine Crops; (2) Field & Vegetable Crops; (3) Cool-Season Vegetable Crops; and (4) Virus diseases of Perennial Plants. Each Specialist covers a range of research and extension needs within their programmatic area.

**A) Research:** The CE research programs in plant pathology emphasize two broad themes: Disease etiology and epidemiology, and disease control. While specific research projects tend to address emerging or chronic problems for which solutions are needed, our Specialists address them in ways that increase our basic knowledge of pathogen biology, epidemiology, and ecology. Some of the research done by our Specialists (e.g., canopy thinning in grapes to reduce Botrytis bunch rot) has had a significant impact on industry practices. Other research seeks safer alternatives to environmentally-damaging pesticides (e.g., methyl bromide) or seeks to predict episodes of disease risk and thereby maximize the efficacy of fungicide applications. While serving to address critically important issues of precision disease control and minimization of pesticides in the environment, this research contributes to fundamental knowledge of pathogen biology, epidemiology, and ecology.

Etiology (the study of disease causation) is a critically important aspect of plant health research that is carried out largely by the department's CE Specialists. With their close connections to county advisers, Specialists are often the first to be approached for help in identifying new diseases. While contributing to our base knowledge of pathogens and diseases, this responsibility often places Specialists at the front lines of California's efforts to detect and monitor new and emerging disease threats.

**B) Teaching:** Our CE Specialists are fully integrated into department activities. This has been particularly true in the area of graduate student education, where CE Specialists direct graduate student research, serve on M.S. and Ph.D. examination and research committees, and contribute to instruction in both undergraduate and graduate courses. Indeed, the expertise of Specialists in disease etiology and diagnosis, the diseases that occur on various commodities, and the identification and cultivation of mushrooms, makes them vital contributors to our teaching programs. Acknowledging the critical nature of this role, through assignment of I&R appointments in appropriate cases, is an important priority.

**C) Knowledge extension:** The CE Specialists in our department provide expertise in plant pathology to county-based Advisors, industry, and the public in northern and central California. Avenues of communication include personal contacts, phone contacts, mail correspondence, newsletters, various state and county meetings, and the Internet (especially in cooperation with the UC IPM Project). Specialists interact closely with AES faculty in Plant Pathology and other campus departments to ensure the application of the most promising new technologies to pest management problems statewide. As a result of these efforts, the implementation of innovative disease control programs in California continues to serve as a model for agricultural production throughout the world. The internet provides an increasingly valuable information delivery tool

and will help us to expand the reach of our extension programs, and to provide clientele groups with the most current possible information. While our department has made some inroads into this communication medium for delivery of extension materials, this is an area needing significant development over the coming years.

**D) University and public service:** CE Specialists serve as members of departmental and college committees, serve as liaisons between AES faculty and county-based Advisors, and serve as liaison officers to commodity boards. They also provide advice to AES faculty on important mission-oriented or fundamental research needs, and participate in departmental and curricular planning. Specialists devote a significant amount time to plant disease diagnosis in support of county Advisors, other department faculty, students, and other University Specialists. This diagnostic service helps address immediate needs, but also keeps the Specialists and the department informed on the occurrence, distribution, and severity of diseases and any new problems needing attention. This is a vitally important service and must be supported to assure the long-term health of California agriculture.

**E) Priorities:** The CE programs in plant pathology have a demonstrated record of accomplishment. Their ability to serve California agriculture, and the missions of the University's Division of Agriculture and Natural Resources (ANR), could be significantly enhanced by campus and ANR commitments to improve physical facilities at Davis, the Kearney Agricultural Center, and the USDA/UC Vegetable Research Center at Salinas. While we are generally understaffed in CE (given the statewide needs for disease control research and education, and the high priority ANR places on this mission) we recognize one significant gap in our CE programs in the area of "ornamentals." The nursery/ greenhouse/ ornamentals areas comprise a $1.75 billion/year industry in California, and a CE Specialist in this arena would be most logically housed at Davis. There is also a critical need to fill a position that was vacated by the recent retirement of Beth Teviotdale, who held responsibilities for fruit and nut tree crops in the San Joaquin and Sacramento Valleys. If a current CE specialist (Gubler) chooses to retire during the current planning window, we would seek to refill that position, which would have responsibilities for grapes and other fruit or nut producing crops.

**Grape and other fruit and nut crops**

Grapes are one of the most valuable agricultural commodities grown in California. This includes table grapes, raisins and wine grapes. The retail value of California wine was recently estimated to be over $16 billion on an annual basis. Other large and valuable fruit crops produced in California include strawberries, pears, apples and stone fruits. Successful production of all these crops requires continuing attention to a wide array of disease problems. As a result of changing agricultural practices and the introduction of exotic pests, there is a continuing need to establish the etiology of diseases not previously seen in California, and to develop appropriate control measures. In addition, various factors, including an increasingly restrictive regulatory environment, may soon preclude the use of practices currently employed to manage diseases already present. Consequently we anticipate recruitment in this area should the current CE specialist holding these responsibilities (Gubler) elect to retire within the current planning window. The importance of this position is underscored by the very large and well-funded program currently maintained by Dr. Gubler. As is currently the case, this position would be located on the Davis campus and would carry statewide responsibility for research and extension on grapes, strawberries, apples, pears and other perennial fruit and nut crops. In addition, we expect that a person in this position would contribute to our teaching program, at least in part through participation in, and perhaps sole responsibility for, a course on diseases of grapes.