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Trends in Plant Pathology—Significance for the Future

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I clearly recall when I received the news that I was to be the President of the American Phytopathological Society that I was pleased to receive what I consider to be a significant honor but also apprehensive about the duties and responsibilities associated with the position. One of my thoughts then, and many times since, was, what will be the theme of my presidential address?

We are all quite naturally influenced by our experiences and interests. In my case, I have had an opportunity to serve more than 10 years in an administrative role both as a department chairman and as acting dean. This has given me some perspective on the challenges associated with research administration. I have always had an interest in history and, much to the dismay of my wife Connie, I am reluctant to throw anything away. Because of this tendency to be a collector, I have essentially all the program books for the APS meetings since 1961. It occurred to me that an analysis of the presentations at the meetings should give some indication of research trends and evolution of thinking during the past 28 years. These then might serve as a basis for discussing what I perceive to be opportunities and potential problems for our profession and our Society in the future.

To avoid an unmanageable amount of data, I selected 10 meetings spaced about 3 years apart, except 1987 and 1988, to examine in detail. First, however, I examined trends in the total number of presentations at meetings, attendance at meetings, and membership in APS.

APS Membership and Meeting Attendance

Presentations at our national meetings dramatically show the steady increase in both size and activity of APS. In the early 1960's, a meeting consisted of about 200 oral presentations. Here in San Diego, the combined oral and poster presentations total 829.

Statistics on Society membership and meeting attendance are only available since 1974. It is apparent, however, that during the past 14 years, there has been a steady and essentially parallel increase in APS membership and meeting attendance. We should be aware that membership has plateaued in the last 5 or 6 years. It is interesting that member participation in the national meetings has grown more rapidly than either membership or attendance. From 1974 to 1988, Society membership and meeting attendance increased 33–34%, whereas over this same period the number of presentations increased 48%. In addition, a very noticeable trend has been the increased number of posters at annual meetings. In 1980, 7% of the presentations were posters and here in San Diego 37% of the presentations are posters.

The message is clear that APS members view the annual meeting as an extremely important professional activity. The attendance at meetings has kept pace with the increasing membership, and the level of participation in meetings has actually expanded. This is a very positive indication of the health and vitality of our Society.

Research Trends

My analysis of research trends in plant pathology in the United States is based on presentations, both oral and poster, at our national meetings. Fortunately, for my purpose, since 1961 the categories used to classify contributions have remained virtually constant.

The first impression one receives when examining the data is the remarkable stability of research emphasis. Ninety-four percent or more of the presentations are included in six major classifications. These are disease, by crop and causal agent; causal agent; control; disease-pathogen interaction, physiology, biochemistry, and molecular biology and genetics; soil microbiology and root disease; and epidemiology, disease detection, and disease loss (Table 1). There has been relatively little variation among these research areas.

Of the major categories, the largest, not surprisingly, is the combined grouping of diseases, identified either by crop or by cause. Presentations in this area averaged 34.4% of the total, ranging from 43% in 1961 to 28% in 1987. A closer examination of the data reveals that during the late 1960's and early 1970's few presentations were identified as being directed toward crop diseases (Table 2). This may reflect meeting organization. It is interesting to note, however, that this period is when research reports on host-pathogen interaction, physiology, etc., contributed a very high proportion of total presentations. Regardless, reports of research on crop diseases reappeared in about 1977 and in 1988 reached the highest level since 1961, constituting 22% of the total. Forest pathology has remained fairly constant with a slight decline to 6% in 1988 from a high of 9% in 1977. The relatively few reports on crop diseases from 1964 to 1974 does not reflect a reduced activity on diseases in general. During this period most of the presentations were grouped in sessions based on the causal agent (Table 2). In recent years, however, there has been a steady and dramatic decline in research presentation on diseases identified by causal agent. This category was stable at about 25% of the total from 1964 to 1977; from 1977 to 1988 it has dropped to only 8%.

There also has been a shift toward more disciplinary research on the major groups of plant pathogens (Table 3). This may account for the decline in disease research identified by cause. Activity in plant virology has been consistent, and relatively high from 1961 to the present, with a rather dramatic increase this year. In the early 1980's, increased interest in bacteriology became apparent and has steadily increased. In 1987 and 1988, papers on mycology have appeared and these are largely on the molecular biology of fungi.

Presentation of research on plant disease control has been consistent at about 15% of the total for the past 28 years (Table 3). Beginning in the early 1980's, there has been a shift from research on chemical control and resistance to biological control. In 1977 17% of the total presentations were on disease control and 2% were identified as biological control, 7% chemical and 8% resistance. In 1988 14% of the presentations will be on control, and biological control will account for 6%, chemical and resistance each at 4%.

Two other research areas that have been relatively stable since 1961 are soil microbiology and root diseases and epidemiology, including plant disease detection and plant disease loss. Since 1980 there has been a slight decline in papers on soil microbiology and root disease. This probably does not reflect decreased emphasis, but rather that much of the work in the area of biological control is with soilborne pathogens.

Research on postharvest pathology and mycotoxicology appeared in the early 1970's and the number of presentations has been fairly steady at 2–4% of the total to the present. Contributed paper sessions on seed pathology appeared in the mid-1980's.

A question of major interest is what changes have occurred in the relative distribution between research in the area of etiology, control, epidemiology, ecology, which I have termed for convenience "organismal" and the area of host-parasite interaction disease and pathogen physiology, biochemistry, and molecular

biology and genetics, which I am referring to as "cellular and molecular." To obtain a general answer to this question, for the years selected for analysis, each presentation, whether oral or poster was placed in one or the other of the broad general fields described above.

It is apparent from the data that although there has been a steady increase in the total research activity in plant pathology, the distribution between organismal and cellular and molecular has remained essentially constant (Table 4). For a 19-year period (1970–1988), the percentage of presentations directed toward disease and pathogen physiology, biochemistry, and molecular biology has averaged 31%, with a high of 33% and a low of 26%.

The peak activity in this area was in the mid-1960's. The percentage in 1964 was 46%. It is interesting to note that at the 1969 meeting in Spokane the general session, with featured speakers Sterling Wortman and James G. Horsfall, focused on the continuing need for applied research in agriculture to meet the world food crisis. There was concern at the time that research in

TABLE 1. Research emphasis in U.S. plant pathology, 1961–1988[a]

Research Areas	Distribution by year (percent of total)									
	1961	1964	1967	1970	1974	1977	1980	1984	1987	1988
Disease—crop	29	11	9	5	7	17	16	17	17	21
Disease—cause	14	26	20	25	29	24	19	18	11	8
Causal agents	15	19	28	16	9	12	11	12	18	25
Control	12	14	8	15	11	17	13	19	13	13
Disease—pathogen physiology biochemistry, molecular, biology, genetics	19	18	22	17	17	12	13	14	17	13
Soil microbiology and root disease	8	9	10	12	12	12	13	8	8	6
Epidemiology, disease detection and loss	4	3	2	5	8	3	9	7	7	8
Other[b]	0	0	0	4	6	2	5	4	8	7
Total (#)	(221)	(180)	(274)	(260)	(438)	(424)	(586)	(819)	(727)	(829)

[a] Based on presentations at annual meetings of American Phytopathological Society.
[b] Primarily postharvest, mycotoxicology and seed pathology.

TABLE 2. Distribution of research activity on diseases distributed among crops and classes of causal agents[a]

Research areas	Distribution by year (percent of total presentations)									
	1961	1964	1967	1970	1974	1977	1980	1984	1987	1988
	Diseases—crops									
Cereal and field	10	2	2	0	0	3	2	4	5	7
Fruit and nut	0	0	2	0	0	0	0	0	2	2
Ornamentals and turf	4	2	0	0	0	2	3	4	2	4
Vegetable	3	0	0	0	0	3	2	2	2	3
Forest tree	8	7	5	5	8	9	8	7	6	6
Crop total (#)	(55)	(20)	(25)	(12)	(33)	(73)	(92)	(143)	(121)	(174)
	Diseases—causal agents									
Bacterial	4	9	6	9	8	10	8	5	3	2
Fungal	4	9	5	5	8	3	8	6	3	2
Viral	6	8	3	10	6	6	3	3	4	3
Nematodal	0	0	4	0	3	2	0	2	0	0
Abiotic—air pollution	0	0	2	2	5	4	0	2	1	1
Causal agent total (#)	(31)	(46)	(55)	(66)	(129)	(105)	(111)	(146)	(79)	(66)
Total presentations (#)	(221)	(180)	(274)	(260)	(438)	(424)	(586)	(819)	(727)	(829)

[a] Based on presentations at annual meetings of American Phytopathological Society, 1961–1988.

TABLE 3. Distribution of research activity in the areas of causal agents and control[a]

Research areas	Distribution by year (percent of total presentations)									
	1961	1964	1967	1970	1974	1977	1980	1984	1987	1988
	Causal agents									
Bacteriology	0	0	0	0	0	0	0	3	7	9
Mycology	0	0	0	0	0	0	0	0	2	4
Virology	6	14	11	12	9	12	9	9	7	12
Nematology	10	5	17	5	0	0	2	0	2	1
Causal agent total (#)	(34)	(35)	(77)	(42)	(39)	(50)	(64)	(98)	(128)	(215)
	Control									
Biological	0	0	0	0	0	2	4	8	6	6
Chemical	6	5	5	7	3	7	6	6	4	4
Resistance	6	9	3	8	8	8	4	6	3	4
Control total (#)	(26)	(25)	(23)	(39)	(49)	(75)	(80)	(159)	(95)	(116)
Total Presentations (#)	(221)	(180)	(274)	(260)	(438)	(424)	(586)	(819)	(727)	(829)

[a] Based on presentations at annual meeting of the American Phytopathological Society, 1961–1988.

plant pathology was moving away from studies in the areas of etiology, control, epidemiology, and ecology. During the succeeding two decades, this has not occurred.

Balance in Plant Pathology

In my view, this is extremely important. Plant pathology occupies a key position in the agricultural sciences because plant diseases have a significant impact on major aspects of agriculture such as cropping practices, quantity and stability of yield, and production costs. In addition, plant pathology is unique among the plant sciences. Our discipline is distinguished from other plant sciences in that we focus on interactions. These include the complex interactions at the cellular or molecular interface between higher plants and microbes that results in either plant health or disease as well as interaction among plants, pathogens, and the biological and physical environment.

Plant pathology is therefore characterized by breadth of training. background, experience, and, perhaps most importantly, perspective and view point. There is a continuum within our science from ecology and epidemiology to molecular biology and molecular genetics. Often the research of the individual plant pathologist will encompass a significant portion of this continuum. It is essential, however, that our academic departments, with responsibility for training plant pathologists of the future, reflect the entire continuum. Certainly, the research, teaching, and extension activities of our discipline must maintain the continuum from interactions at the organismal level to those at the molecular level, and the knowledge gained by research on these interactions must be translated into plant health management.

To accomplish this requires balance among the many diverse components we recognize as constituting plant pathology. The importance of balance has been repeatedly and effectively addressed by leaders in our science. Luis Sequeira in his presidential address in 1986, Abe Epstein in his editorial in *Plant Disease*, James Jorsfall in his address at Spokane in 1969, and many other examples could be given.

There is, I think, no argument that balance is essential, but what is the most appropriate balance to maintain? This, of course, is a subjective and philosophical concept and cannot be precisely defined. I believe, however, that in practical terms plant pathologists over the past three decades, by their collective activities reflected in the presentations at the annual meetings, have defined the balance that over that period has characterized plant pathology.

By most criteria that might be applied, I feel our discipline and APS has prospered during the past 30 years, and thus the balance among the various subdisciplines must be relatively sound.

We cannot, however, assume that the pattern established in the past will continue into the future. Indeed, it may not be desirable for this to occur. There have been trends and shifts in direction in the past, and it is inevitable that there will be changes in research emphasis in the future. The essential point, however, is that changes should be the result of conscious decisions and actions.

Accordingly, we should attempt to identify the external forces and events that potentially will impact on plant pathology. We must then try to assess whether or not the trends we anticipate are favorable or unfavorable and develop a plan of action that will maintain the viability of our science.

As I have indicated earlier, plant pathology is unique in being both an agricultural science and a plant science. Consequently we must be aware of and responsive to the complex scientific, societal, and political environment in which we must function. There are certainly many issues of importance to plant pathology and I'm sure we would all compile a fairly similar list, although priority ranking would undoubtedly vary.

I consider two areas extremely important to the future of plant pathology. These are research funding patterns and the impact of biotechnology. They are, of course, interrelated and this contributes to the significance of each.

Research Funding

Historically, a significant level of funding for research in plant pathology has come through the agricultural experiment station. These resources are a combination of federal and state funds.

> Federal funding for university-based agricultural research programs was $292.3 million in 1985, including $198.9 million for formula programs, Hatch Act, McIntire Stennis Act, animal health, and 1890 research. Originally, formula funds were a major source of research dollars, but the relative share of Hatch Act funds for agricultural experiment stations has declined as state support has increased. States are providing about $4 for every Hatch Act dollar, $622 million in 1984.

(FY 1987 Budget Recommendations, Division of Agriculture, NASULGC)

At our meeting in Cincinnati, Dr. Jack Barnes, in his talk commemorating the Hatch Act Centennial, presented an insightful analysis of research funding patterns. His data show that from 1970 to 1985, based on 1984 constant dollar, formula funding to plant pathology increased by only 20% and nonfederal funding increased by 45%. During this same period, grant funds increased by 33%. Agricultural experiment station funds contribute a substantial portion of the research budget for plant pathology departments. It is important to realize, however, that approximately 85–95% of these resources are allocated for salaries and fixed expenses. The money available to directly support research is woefully inadequate to maintain strong, productive programs. Consequently, we are becoming increasingly dependent on funding from extramural sources.

A very important source of support comes from commodity groups. The emergence of commodity funding for research is one of the most significant trends in research support in recent years. Based on the financial situation facing agriculture, it appears unlikely that there will be an appreciable increase in the level of commodity support. Although these funds are extremely useful in general, they are not available for research that is not directly related to plant health management. The availability of commodity funds may be responsible in part for the apparent resurgence of research on crop diseases. The appropriation of funds at both the state and federal level for IPM programs may also have contributed to increased research on crop diseases. Certainly, an appreciable amount of control research is supported by commodity funds.

A second major source of extramural support are the grant programs established by the federal government and by various foundations. These funds. however, are primarily designated for

TABLE 4. Distribution of research emphasis in U.S. plant pathology that may be categorized as either organismal or cellular and molecular [a]

	Distribution by year (percent of total)									
Research emphasis	1961	1964	1967	1970	1974	1977	1980	1984	1987	1988
Organismal[b]	64	54	57	69	69	66	74	70	67	67
Cellular and molecular[c]	36	46	43	31	31	33	26	30	33	33
Total (#)	(221)	(180)	(274)	(260)	(438)	(429)	(586)	(819)	(727)	(829)

[a] Based on presentations at annual meetings of the American Phytopathological Society, 1961–1988.
[b] Includes etiology, control, ecology, epidemiology.
[c] Includes disease and pathogen physiology, biochemistry, molecular biology, and genetics.

research programs with objectives directed toward understanding host-pathogen interactions at the cellular and molecular level. There remains, therefore, a dearth of funding to support research on organismal ecology, biology, and epidemiology. I believe this is highly significant when we evaluate the potential for modern biology to significantly contribute to improving plant health. There is, of course, considerable research being done by the various agriculturally related industries. These programs also tend to be focused either on disease management employing biological chemical or resistance approaches, or through manipulations at the molecular level. Research within the ARS of the USDA dates back to the beginnings of plant pathology in this country. ARS research encompasses the entire scope of plant pathology, and USDA scientists have contributed substantially to the balance that has been maintained for the past 30 years.

Impact of Biotechnology

What is the impact of biotechnology on plant pathology and how will this revolution in biology influence the future of our profession? Even to a non-molecular biologist, such as myself, the potential for recombinant DNA technology to not only enable researchers to gain an understanding of fundamental biological processes but to genetically engineer plants and microbes for the benefit of mankind is readily apparent. The latter aspect of biotechnology, the capacity to modify organisms, is of great significance to plant pathology.

Research to address fundamental questions such as the basis for host-pathogen specificity and the mechanisms through which pathogens cause disease has been actively pursued for decades. Recall that in the 1960's almost 50% of the presentation at national meetings dealt with studies in this area. Although these investigations contributed significantly to our understanding of the disease process, it was difficult to envision the practical application of this research. The situation today is quite different. It is broadly recognized that agriculture provides a major opportunity to exploit biotechnology for both scientific and economic gains. Within agriculture, considerable emphasis is being placed on genetically engineering plants and microbes to provide innovative ways to protect plants from disease. This has resulted in moving plant pathology more toward the center of biological research. As is often the case with change, there are advantages and some potential disadvantages. More researchers are studying host-pathogen systems at the molecular level, and funding for research in this area has increased. In many cases, however, an appreciation of the concomitant organismal and ecological investigations needed for the effective application of this research to the solution of problems appears to be lacking.

The science of plant pathology has received widespread recognition, and I feel it is more fully appreciated by both the scientific community and society. Unfortunately, many of those involved in studying the molecular interaction of host-pathogen systems do not identify with plant pathology and do not feel our Society has anything to offer. This trend could lead to problems for our profession and for the APS.

There are few statistics to indicate the magnitude of this potential problem, but data on student enrollment in the past few years is suggestive. There has been in the past four years a decline in student memberships in the APS. From 1974 to 1984 the percentage of student members remained essentially constant at about 18.19%. In 1988 this percentage had dropped to 13%.

In 1982, an annual departmental survey was initiated. One part of the survey is directed toward obtaining information on student enrollment in departmental graduate programs. These data show that the number of students in plant pathology departments throughout the country has not appreciably declined. A comparison of the two sources of information on students reveals that in 1982 84% of the students identified by departments were APS members. In 1988 this figure had dropped to 61%. Today there are approximately 345 students in plant pathology departments who are not members of APS.

Finally, an examination of the positions advertised in *Phytopathology News* provides clear evidence of increased emphasis in the area of molecular biology. I have only considered tenure track positions in U.S. Departments of Plant Pathology because this is where the next generation of plant pathologists in our country will receive their training. Over the past 36 months 72 positions have been advertised. Of these 16% were in extension, 42% in etiology, control, ecology, and epidemiology, and 42% in molecular biology and genetics. Inclusion of the extension positions with etiology, control, etc., gives a 58-42% distribution between what I have been referring to as "organismal" and "cellular-molecular" compared with a 66-34 distribution between these areas in research presentation at this national meeting.

I think there is reason to believe that the research emphasis in plant pathology is closer to the 58-42 split indicated by position announcements rather than the 66-34 distribution suggested by meeting presentations. There are certainly faculty, postdoctoral fellows, and students in university, industry, and ARS laboratories whose research could be categorized as molecular biology who rarely attend APS meetings.

I am not particularly concerned about which distribution is closest to reality. I do, however, believe that a real danger exists that extramural fund availability will upset the balance that has been established over the past 30 years. Research programs in areas where funds are available will expand, investigators will shift emphasis into areas where funds can be obtained, and available positions will be directed toward fundable areas. An extremely undesirable scenario is that research directly related to plant health management will be supported primarily by commodity groups with some Agricultural Experiment Station funds for IPM, sustainable agriculture, etc. Research on plant-microbe interactions will be funded by granting agencies, and foundations and the central area of organismal biology will be largely abandoned. It would be highly unwise to fail to recognize that such a development in research emphasis is conceivable, and I believe we must do everything possible to be certain it does not occur.

There is also a need for funds to apply the technology that is available today. I believe it is shortsighted to provide funds to develop new knowledge and not follow up with resources to enable this information to be used in a practical and beneficial way.

Directions for the Future

In conclusion, I wish to offer the following propositions at three levels and in three interrelated areas. At the federal and state level, I urge increased funding for research on organismal ecology, biology, and taxonomy. The support for biotechnology is fully warranted and perhaps should be augmented. In my view, however, it must be recognized that the vast potential of biotechnology to contribute to the solution of problems in agriculture and natural resources will never be fully realized without research to determine the fitness of genetically altered organisms to survive and function in natural ecosystems. We must have new information and greater knowledge of biological systems and we must learn how to use this knowledge for the benefit of humankind. This cannot be effectively accomplished unless research support is broadly based.

I would therefore urge that the USDA Competitive Grants Program be dramatically augmented and expanded. Our Society is not alone in calling for increased support for agricultural research. For example, the American Society for Microbiology recommended that the Competitive Grants Program be funded at a level of $132 million in FY 1989, an increase of $90 million over fiscal 1988. This level was proposed to provide some parity between research funded by USDA and that funded by the National Science Foundation.

Furthermore, the Board of Agriculture is preparing a report on funding needs in the food and agriculture sciences. The basic recommendations will call for a $500 million increase in competitively awarded funds. This increased level of funding would be phased in over three fiscal years, with a minimum of a $150 million increment in the FY 1990 budget.

Secondly, I would urge academic departments and USDA and

industry laboratories to structure the staffing and research programs in their units to maintain a balance throughout the diverse areas that encompass plant pathology. What this balance should be is of course debatable. I would submit, however, that the distribution of research activity in what might be considered the six major areas of plant pathology over the past 30 years provides a realistic benchmark.

The availability of research support and subdisciplinary balance are closely interrelated. It is very difficult, particularly in academic departments, to commit positions to research areas, no matter how important, if funding is not available to allow faculty to develop productive programs. I view this as a major concern because, if departments are to offer sound and relevant graduate programs, they must have faculty who are able to provide instruction and research guidance in all the primary areas of plant pathology.

Lastly, I urge all members of APS to recognize that the molecular and cellular aspects of host-pathogen interactions is an integral part of plant pathology. I strongly believe that the increased recognition of the potential benefit that can be realized by applying tools of modern biology to host-pathogen systems is one of the most significant developments in the history of our science. I view it as imperative that we not allow research directed toward answering fundamental questions, such as the basis for host-pathogen specificity, to drift away from plant pathology. I therefore strongly urge everyone to support the journal recently established by APS, *Molecular Plant-Microbe Interactions*. Those working in the area—submit your best research to *MPMI*. To those in other areas, recognize that the success of *MPMI* is critical to our future.

The existence of *MPMI* as a journal associated with APS provides a clear statement that research on the underlying mechanisms of interactions that form the basis of our discipline will continue to be part of the continuum that is necessary if plant pathology is to retain its position as a key member of the biological science community.

I believe that we can be justifiably proud of the contribution plant pathology has made to both agriculture and biology. Today, as our science receives greater recognition and new opportunities and challenges arise, we must strive to retain the breadth and the balance that forms the foundation of plant pathology.