

Nematology—Status and Prospects: Let's Take Off Our Blinders and Broaden Our Horizons¹

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Abstract: Some aspects of current fundamental nematological research and teaching in agriculture, soil zoology, biology and medicine, and parasitology are explored as they relate to the Society of Nematologists and the science of nematology in its broadest sense.

My main objectives are to discuss first my views on the current status of the Society of Nematologists in the United States, second the importance of basic research in nematology, and third the opportunities in nematology for major contributions to science and mankind. These objectives are interrelated and of importance to this gathering. I thank colleagues within and outside the Society who have given me their ideas as I considered this subject. In his 1964 presidential address J. N. Sasser (6) expressed the view that the underlying philosophy of our new society is that the *nematode* is the hub of the wheel and that the spokes are the various subject matter areas which must be studied and advanced if we are to understand the hub. Our society organization, then, serves as the rim of the wheel and provides a framework within which scientists with similar interests can

meet, discuss their work, and use the resources of an organized body to promote and advance the science of nematology. This means, then, that if we, as a Society of Nematologists, are to consider nematology in its broadest sense, we need to band together into a single membership and advance the frontiers of knowledge for all groups and not just one or two.

We should reaffirm and emphasize this position taken by Sasser during our formative years. Others who have written on this subject include Mai (5) and Ferris *et al.* (3). Although I attempt in this presentation to make a strong case for fundamental research in nematology, I am not suggesting that there isn't an equally strong case for applied research or that I am opposed to applied research.

CURRENT STATUS

I would like to share with you my view of the Society of Nematologists (SON), add some background on basic research, and propose some suggestions. In 1961 a critical mass of scientists interested in nematodes

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formed a society to foster and promote the science of nematology. In 1968 SON began publishing its own journal. Now, 18 years after the Society was formed, there is a growing cadre of scientists who work and study with nematodes but do not belong to our society or publish in our journal. There is growing concern by many of our members that the field of nematology has plateaued or may even be shrinking. This view is strengthened by recent reallocations of nematology positions in universities and agricultural experiment stations as nematologists have retired or transferred to other kinds of work, and as state and federal hiring has been postponed. I also feel that some recent society decisions tend to limit and narrow its horizons, and that we are becoming isolated, returning to the plant nematology image that some of us tried to leave behind when we formed the Society in 1961. We are rapidly becoming a friendly club that spends much of its time talking to itself.

Supporting my reasoning is our apparent unwillingness to participate in, or affiliate with, other societies and our concentration of publications in our own journal. JON is a fine, well-respected journal, but its readership and its authors are still a restricted group. In support of JON our membership has reduced its publication in other broader scientific journals, such as *Phytopathology*, *Proceedings of the Helminthological Society of Washington*, *Journal of Parasitology*, *Journal Experimental Parasitology*, *Experimental Zoology*, and *Zoology* bulletins. Every year we become more comfortable and isolated in our little ecological niche. We become less challenged by the creative thinking of other biologists and scientists. We are losing touch with the scientific community around us. The broader scientific community is moving on without us. If we continue down our path of isolation and conservatism I fear we may be headed for extinction. Maybe we should take a lesson from the very organisms we are studying. They parasitize every living plant and animal, inhabit every ecological niche, and are able to survive the most adverse environmental extremes.

RESEARCH

Let us explore some aspects of funda-

mental nematological research in four general areas: agriculture, soil zoology, biology and medicine, and parasitology.

Agriculture: Fundamental research on the biology and ecology of plant parasitic nematodes is the foundation of good nematode pest management. This is borne out by a recent survey on Integrated Pest Management conducted by the Intersociety Consortium for Plant Protection for the Experiment Station Committee on Organization and Policy (4). About one-third of our present scientist years in nematological research in the Agricultural Experiment Stations is devoted to basic biology and ecology (Table 1). Fundamental research areas projected for 1979-80 which received both a high priority index (more than 50) and a high manpower need (more than 3 scientist years) were population dynamics, taxonomy, abiological parameters, biological parameters, developmental biology, and physiology.

In response to a 1979 request from the Secretary of Agriculture, the Society of Nematologists identified five major priority research areas in need of additional funding (Charles Heald, personal communication). They were integrated pest management, chemical control alternatives to soil fumigants, plant breeding for resistance to nematodes, biological control, and basic ecological studies. Some fundamental research is obviously distributed through, and included in, all of these areas. Fundamental research in ecology stood by itself as a high priority area.

There appears to be a continuing and pressing need in agriculture for basic research on the biology and ecology of plant parasitic nematodes. Population dynamics, economic thresholds, environmental factors, and biological alternatives to chemical control appear to be high priority research areas. Integrated pest management and biological stress in crop production appear to be key areas which are currently receiving special and additional financial support at the state and federal levels. In California the legislature has just funded an additional million dollars for pest management research in 1979-80. Nematologists with a special interest in crop production should focus on, and try to identify with, these areas.

TABLE 1. Nematology priorities and manpower requirements in fundamental biological and ecological research as projected by State Agricultural Experiment Station personnel in pest management disciplines.*

Priority research areas	Priority index	SY 1978	Additional SY 1979-80
Fundamental biology			
Survival		0.9	2.5
Taxonomy	125	2.4	6.0
Developmental	109	1.2	3.6
Behavior	77	1.0	1.9
Physiology	65	2.3	3.0
Genetics	61	1.0	2.2
Subtotal	20	8.8	19.2
Fundamental ecology			
Population dynamics	316	6.6	12.5
Abiological parameters	150	0.9	5.7
Biological parameters	131	2.4	4.6
Population modeling	60	0.7	1.8
Geographical distribution	27	0.2	0.6
Subtotal		10.8	25.2
Total biology and ecology		19.6	44.4
Total pest management and control		42.1	96.4
Grand total		61.7	140.8

*ISCPP Report 1979.

Soil zoology: During the last 10 years, soil zoologists have increasingly recognized nematodes as the most numerous metazoans present in natural soil habitats, playing a role in litter decomposition and nutrient cycling. Soil zoologists are beginning to consider nematodes as soil "regulators" and "transporters" of other soil microbes and fauna. Plant nematologists have a strong tendency to view soil nematodes only as plant "regulators" or "vectors" of disease agents. The dynamics of energy and nutrient transfer in soil is one of the current and major research topics in soil ecology, and nematodes appear to have a piece of the action. As plant nematologists we often view biological control agents solely in their role as predators or parasites, and outside the soil micro-flora and fauna community. We might better try to understand the whole community as do soil zoologists. A bibliography of soil zoology papers from 1968-78 dealing with nematodes prepared by the Society of Nematology Ecology Committee illustrates some important fundamental research areas (Table 2). The major areas dealt with in these papers were ecosystems production, basic biology, community production, parasite-predator relationships, en-

TABLE 2. Fundamental soil zoology papers reporting nematode activities, 1968-78.

Topic	Papers
Ecosystem productivity	67
Basic biology	50
Community structure	44
Parasites-predators	34
Energetics	13
Microcosms	12
Distribution	2
Total papers	222
Total authors	228
SON members	54

ergetics, and microcosm studies. It is interesting to note that only about one-fourth of the 228 authors were listed as 1978 members of the Society of Nematologists. This data would suggest that there is a sizeable number of zoologists and their students studying soil nematodes with whom we need to communicate as scientists and as the Society of Nematologists. One of the major attributes of their perspective is their broad view of nematodes as members of the total soil flora and fauna rather than a narrow view of nematodes as single disease agents. On the other hand, they don't know very much

about the nematodes themselves and are often located at institutions that do not have trained nematologists. My experiences collaborating with soil zoologists at the University of Alaska, Colorado State University, and New Mexico State University suggest that they welcome the support of trained nematologists.

Biology and medical sciences: The use of nematodes as biological models is attracting wide interest among the biologists and biomedical researchers. For example, at the May 1979 Cold Spring Harbor Symposium on *Caenorhabditis elegans* (1,7), approximately 100 scientists and students presented 80 papers and poster sessions on the general biology, metabolism, genetics, neurobiology, muscle development, and the DNA and RNA characteristics of nematodes (Table 3). They represented 21 universities and research institutes from six countries. The number of scientists listed as members of SON could be counted on one hand. Most of the authors were members of biology, zoology, or medical science departments. These broadly trained scientists use nematodes as research tools because they believe that certain basic cellular processes proceed along similar paths in all living things and they find nematode models are easier to work with than some other metazoan models. Because of this work, information about certain bacteriophagous nematodes is accumulating at a rapid pace and may now outdistance that for any other group of metazoans. Dr. B. M. Zuckerman is editing a new book, *Nematodes as Model Biological*

Systems, suggesting that nematodes may soon reach the status of the *E. coli* of the animal kingdom (8).

Early this year, five nematode papers were featured at the prestigious Gordon Research Conference in the session on the Genetic and Evolutionary Aspects of Aging (2). This compares favorably with the seven papers on all other nonvertebrate organisms. Research on nematode aging began about 10 years ago, and it would appear from the large number of workers from many disciplines working in this area that there is promise and support for the contention that some events which accompany senescence in nematodes are similar to those which occur during mammalian aging. The genetic mapping of *C. elegans* is well advanced, and mutants resistant to acetylcholinesterase inhibiting chemical have been observed and studied for some time by this group of scientists.

It seems reasonable to believe that these and many of the other biological processes going on in *C. elegans* are similar and basic to all other nematodes, including plant-parasitic nematodes. This reservoir of information needs to be better tapped and used by nematologists and by our Society. This is an area where major contributions to science are being made. Yet little of it is being communicated within the arena of the Society of Nematologists.

Parasitology: Nematode parasites of animals have provided the oldest tool for fundamental nematological research. It is interesting to note that current fundamental research on animal nematodes follows a pattern very similar to that being followed with plant nematodes (Table 4). Morphol-

TABLE 3 Fundamental research topics reported at the Cold Springs Harbor Symposium on *Caenorhabditis elegans*, 10-13 May 1979.

Research topic	Paper presentations	Poster sessions
Genes and development	11	20
Sex	6	3
Neurobiology	8	1
Muscle	6	1
DNA and RNA	6	4
Metabolism	—	5
Behavior	—	3
Techniques	—	6
Total presentations	37	43
Total authors	99	
SON members	2	

TABLE 4. Fundamental research citations in Helminthological Abstracts during the first 3 months of 1979.

Subject	Papers	
	Series A Animal nematodes	Series B Plant nematodes
Morphology-taxonomy	74	66
Ecology-life history-distribution	36	59
Biochemistry-physiology	69	40
Cytology-genetics	9	11
Total papers	188	176
Total classified abst.	1,505	460

ogy and taxonomy papers dominate both fields. Biochemistry-physiology is the second most prolific area in parasitology, while ecology-life history research area studies are second in plant nematology. One of the reasons biochemistry-physiology research is pursued so vigorously in parasitology is the interest in immunology research. A review of the 72 most recent papers on the Nematoda published in the *Proceedings of the Helminthological Society of Washington*, *Journal of Experimental Parasitology*, and *Journal of Parasitology* suggests that—in the fundamental areas—biology, immunology, biochemistry, metabolism, taxonomy, ultrastructure, and morphology are the current major topics of research by parasitologists (Table 5). It was interesting to note that there were five papers on nematode-microbial interactions, suggesting that this

may be a new and important research area. I could identify only five SON members out of a total of 150 authors, which would suggest that we have not succeeded in bringing many of these scientists into SON or in building a lasting bridge between plant nematologists and the animal nematologists.

TEACHING

There is also a need to broaden our training program. Nematodes are interesting organisms; they are model animal systems providing ideal research projects for biologists, ecologists, physiologists, and biochemists. Yet the major nematology teaching centers are not training the scientists working in these areas. In the European system most nematologists are broadly trained as zoologists and then specialized by on-the-job training. In a 10-year survey of six of our major nematology training centers (Table 6), 70 of the total 80 Ph.D. graduates have gone into agriculture, and almost half of those are currently employed in a university situation. I find one of the major attractions of our Ph.D. program at Riverside is our flexibility to design a nematology training program for students in biology, entomology, and plant pathology. We are just now beginning to recruit students from areas other than the traditional plant pathology or entomology programs. Sending students into other scientific areas will return our efforts manifold in the future. We also need to develop postdoctoral programs to give specialized training to scientists interested in nematodes but working in other scientific areas. We should try to find students at the

TABLE 5. Papers on nematodes appearing during 1978–79 in *Proceedings Helminthological Society of Washington*, *Journal of Parasitology* and *Experimental Parasitology*.

Subject	Papers
Host range	12
Biology	9
Immunology	9
Host-parasite relations	8
Biochemistry-metabolism	7
Taxonomy	7
Ultrastructure-morphology	5
Survival	5
Chemical control	5
Microbial associations	5
Total papers	72
Total authors	150
SON members	7

TABLE 6. Survey of the job placement of the nematology Ph.D. graduates from six major nematology teaching departments during 1968–78.

University	No. of graduates	Nematology research areas					
		Agriculture			Parasitology	Biology	Other
		Univ.	Gov't.	Priv.			
Cornell	12	6	2	2		1	1
Florida	9		5	3			1
North Carolina	17	11	4	2			
Purdue	10	1	2	5		2	
Univ. of California							
Davis	16	9	2	3			2
Riverside	16	6	6	1	1	2	
Total	80	33	21	16	1	5	4

undergraduate level and get them interested in nematodes before some other biologists recruit them.

SUGGESTIONS FOR THE FUTURE

We need to expand our horizons. We need to think broadly about nematodes as biological organisms. We need to draw on the general scientific community for a continuing supply of new ideas. We need to be better entrepreneurs, promoters, and joiners who have a fascination and love for nematodes as the most interesting and exciting invertebrate group of organisms. We need to join and participate in the other societies and excite and educate them about our passion. Each of us should spend at least a year as a missionary in some other scientific organization.

Not only should the Society belong to other science associations and organizations, we should also foster more special ad hoc subject matter committees with members from other societies, plan joint programs and symposiums, collaborate on books, and so on. Our Ecology Committee is well on the way to doing just that. I hope the Executive Committee will support its actions. We need to make better use of the APS nematology committee. We need more such committees. Early on in our Society history we made an effort to get parasitologists on various committees and editorial boards, even if they weren't members of SON. Somehow that effort has slipped during the last few years. We can't give up if we are not successful in our first attempts.

We need to make a concentrated effort to publish in other journals and encourage other researchers to publish in our journal. As long as we limit our publications to our own journal we will continue talking to ourselves and a very narrow spectrum of science. This has spin-off in other areas, such as peer review and panel reviews for

federal grant applications. Most of our grant applications to NSF and NIH are reviewed by a majority of scientists with broad training in biology. If they knew more about nematodes, our success and support might be greater.

Finally, we need to look within our own society, recognize the various interest groups that already make up our membership, and try to promote and enrich their interest in nematodes and the society. A specific case in point is the area of nematode parasites of insects. Most of the current researchers are members of our society, yet they have indicated that they find little in society programs and may soon drift away if we don't begin to include them in our program planning and society organization.

Are each and every one of you ready to meet these challenges as we head into the 1980s? Maybe they are not greatly different from those of the 1960s and 1970s, but they certainly are tougher.

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