Reports

Editor's Note.—In October 1990, Mary E. Clutter, Assistant Director for the Biological, Behavioral, and Social Sciences (BBS) at the National Science Foundation, requested written testimony on the needs of systematics from the Society of Systematic Zoology for a BBS Task Force Looking to the 21st Century. The testimony was prepared by Julian Humphries, William Fink, and Joel Cracraft and was presented orally to the task force by Michael J. Novacek, President of the Society. This report follows. Since the preparation of the report, the major systematics societies have joined together to formulate a full-length document on research trends and priorities in systematics. This latter report will guide agencies like the National Science Foundation as they establish funding priorities and initiatives in systematics. Further information on this effort will be published in the December issue of *Systematic Zoology*. Co-chairs of the Steering Committee responsible for coordinating the report are Joel Cracraft, Department of Anatomy, University of Illinois, Chicago, Illinois 60680, USA; W. Hardy Eshbaugh, Department of Botany, Miami University, Oxford, Ohio 45056, USA; Norman I. Platnick, Department of Entomology, American Museum of Natural History, Central Park West at 79th Street, New York, New York 10024, USA; and Melinda Denton, Department of Botany, University of Washington, Seattle, Washington 98195, USA. Information may also be obtained from Terry Yates, Director of the Systematic Biology Program, National Science Foundation, Washington, D.C. 20550, USA.—*DMH.*

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Testimony to the BBS Task Force Looking to the 21st Century

Society of Systematic Zoology: Summary

The Society represents over 1,500 scientists whose research programs are aimed at understanding the patterns of life's history, and the processes which generated them. Our membership includes comparative biologists from diverse disciplines, including phylogeneticists, taxonomists, molecular biologists, functional morphologists, developmental biologists, and many others. Systematic biologists are active in development of theory in comparative biology; in analyzing and characterizing the products of evolution—species and higher taxa; and in producing classifications and identification guides to organisms. Systematists are also on the front lines of efforts to quantify and characterize the biodiversity crisis.

Natural history collections play a central, irreplaceable role in systematic studies. Properly conserved, these institutions will serve for centuries to come; we must both expand the resources available to museums and improve the efficiency with which we maintain those facilities.

Most basic and applied research in systematics is funded by the National Science Foundation, although some applied research is funded by other governmental agencies and industry. We present the following recommendations to improve NSF's effectiveness in serving our membership:

- We outline specific propositions that would increase educational opportunities for undergraduate, graduate, and postdoctoral students in systematic biology. We address the issue of providing training for under-utilized pools of talent, and the need for support for scientists from developing countries.
- NSF should understand its unique role in maintaining the intellectual vigor of our science, and the need for serious commitments to funding new technologies and new conceptual areas.
- NSF should utilize the systematics community in assessing the comparative aspects of research funded by other Programs.
- NSF must take a close look at its regulations and application procedures on multi-disciplinary and inter-institutional grants.
- The Systematic Biology Program must remain clearly identified with the highest quality research on comparative and evolutionary biology.

Without taxonomy to give shape to the bricks, and systematics to tell us how to put them together, the house of biological science is a meaningless jumble.

R. M. May, Nature 347:129–130, 1990

What Is Systematics?

Systematics is the scientific study of the diversity and history of life. That is, how did the forms which inhabit (and previously inhabited) the Earth originate, how did they diversify, and how are they dis-

tributed in time and space? Our discipline is concerned with both the pattern of historical evolution of taxa, and with the processes responsible for the diversity we observe. Systematic research most often results in hypotheses of interrelationships among groups of organisms. The results of these labors include species-level descriptions and revisions, analyses of higher taxa, descriptive morphology, morphometrics, biogeography, and exploration of systematic theory. Most systematists consider themselves evolutionary biologists, as well, and use their group of interest to study such topics as speciation mechanisms, coevolution, functional morphology, natural selection, asexual and sexual reproduction, developmental biology, or comparative molecular biology. In its current organization, the Systematic Biology Program covers this broad diversity.

Relevance of Systematics

Systematics produces syntheses that challenge and guide all disciplines that encompass comparative biology. Thus, when formulating hypotheses about what species are, how they originate and diversify, how they compete for resources within their communities, and ultimately how they become extinct, we use a systematic foundation. Clearly, any comparative study of evolutionary biology is intimately tied to a systematic framework.

We must know about species, their interrelationships, and where they live before we can understand their biological roles and their importance to us, and seek effective ways of ensuring their survival. Because not all of the Earth's vast biodiversity can be studied effectively, it is systematics that must also provide a basis for establishing priorities for the study of species; for example, the phylogenetic position of species provides a crucial metric for determining the role an endangered species may play in understanding the evolution of a group. It is systematics that discovers the species, gives them names, and finds their place in the history of life. It is systematics that characterizes areas of endemism where conservation efforts can be concentrated.

Systematic studies have a more immediately pragmatic use as well. Applied scientists are increasingly aware of the benefit of correctly identified and classified organisms. For example, entomologists provide essential service to the agricultural community by identifying and describing insect pest and control species. Botanists are essential for pharmaceutical companies in their search for medicinally important plants such as those used in chemotherapy. In fact, all plant and animal species have potential utility to humans and the predictive value of natural classifications can be significant to any project in search of organisms with a specific set of traits.

An Agenda for Systematic Research

Each of the topics below falls within the purview of systematics and could form the focus of a research proposal submitted to the Systematic Biology Program or the Biological Research Resources Program at NSF.

Theory and methods.—At the very heart of systematics lie the questions: What is the nature of the entities that are the result of the evolutionary process and how can we discover the history of those entities? The framework for asking those questions is a general theory of biological comparison. Development and elaboration of such a theory has always been central to systematics, but in the past three decades there has been more activity, and more progress than ever before. The focus of research on theoretical issues shifts through time, but recent examples of such activity include historical biogeography and species concepts.

Theoretical sophistication without means of application makes for an empty science, and the interplay between theory and methodological application has also been fruitful in recent years. For example, one of the great contributions to systematics over the last decade has been the introduction of a more quantitative, testable component to our research. At the heart of this revolution has been the development of algorithms and computer software to implement theoretical advances. Incorporation of new methods of data acquisition and analysis have also been important, including widespread adoption of computers as standard tools, video systems, and PCR. The latter, a technique which allows recovery of molecular data from museum specimens, will greatly increase applications of molecular techniques in systematics, while confirming the value of traditional museum collections.

Applications.—Theoretical and technical advances both provide the means for and benefit from applications to real-world studies. These can take many forms in systematics, and the following is but one way of organizing them.

Species level studies: The fundamental unit of systematic studies is the species. An essential part of systematics is the identification and placement of species into a natural classification. In some taxonomic groups, where a high proportion of the taxa are still undescribed, such activities are an overwhelming portion of the work to be accomplished. Even in groups that are relatively well known, identification and description remain important tasks.

Revisionary studies: The goal of a revisionary study is a statement of relationships reflecting the natural hierarchy of genealogical relationships among the species and taxa under study. These studies provide the broad framework for multi-species comparative and evolutionary biology and provide the natural classifications into which we place species.

Comparative studies: Systematics draws on a vast array of sources of evidence, including descriptive and functional morphology, behavior, molecular/biochemical data, morphometrics, physiology, ultrastructure, ontogeny, and the fossil record. Comparative studies using these sources of evidence look for generalities underlying organismic evolution and provide the synthetic framework with which to understand the evolutionary context of the data, as well.

Collections.—Natural history collections play a cen-

tral, irreplaceable role in systematic studies. As the repository for millions of biological specimens essential to our profession, the maintenance of these specimens by a trained curatorial staff is paramount. Perhaps in no other scientific discipline do the syntheses that are being produced today rely so heavily on the contributions of past centuries of effort. Properly conserved, these institutions will serve for centuries to come; however, as the number of specimens housed grows (and grow it must if we are to adequately sample the biodiversity of the planet), we must both expand the resources available to museums and improve the efficiency with which we maintain those specimens. Museum collections now serve as the only source of specimens of many extinct or rare species and of distributional data showing how species ranges have changed over the past centuries. New biochemical techniques have expanded our ability to collect new systematic data from museum specimens, thus greatly increasing the importance of specimens already in museums and emphasizing the need to expand these collections for future systematists.

Large, well-curated collections contain information on the structure of ecosystems over long periods of time, allowing insights into historical ecology and changes in their component species over time. The data accompanying museum specimens serve as a baseline against which comparisons can be made for determining what areas need preservation most urgently. Computerized catalogues make these large, complex databases available to workers in numerous disciplines; combined with mapping programs, they form powerful tools towards understanding ecosystem changes over time.

Recommendations on How NSF Can Facilitate Systematic Research

1. Educational Opportunities

A. Infrastructure

Background.—Training opportunities for systematists have diminished over the last decades as some of the major research universities (e.g., Princeton, Stanford) have curtailed their systematic programs and as universities have diminished their support for "pure" systematic positions. Lack of undergraduate exposure to systematics leaves their education on the comparative method incomplete; as they enter research fields, this lack can hinder their pursuit of the highest quality research. The discipline of systematic biology will be actively incorporated into biology departments only to the extent that it is a vital area of science. The burden is primarily on systematists and their societies to demonstrate their vitality to their peers.

Recommendation.—Encourage submission and funding of the highest quality systematic research. Provide ample funds to include students from all levels (undergraduate, graduate, and post-graduate) as research assistants at systematic laboratories and as part of research projects. Funding of collections in smaller educational institutions (perhaps through REU and RUI grants) may encourage employment of systematists and the continuation of collections at these institutions. Funding these collections will also be a contribution to biodiversity efforts, as it is these small collections which often have concentrated assemblages of particular groups of organisms as a result of a single curator's research interests. Improve access to multi-user facilities and natural history collections by supporting their basic expenses, especially for technical support.

B. Postdoctoral Support

Background.—Although Biotic Systems and Resources (BSR) does have some specific programs for postdoctoral fellows, it is unclear what priority has been given to postdoctoral training on systematic research grants. Our impression is that molecular based proposals routinely contain requests for postdoctoral positions, but more traditional studies rarely include such positions. Postdoctoral positions provide young systematists with access to modern systematic facilities and training with established researchers.

Recommendation.—NSF should set clear priorities recognizing the appropriateness of funding postdoctoral positions in all forms of systematic research, and applicants, reviewers, and panelists should all be aware of such priorities.

C. Under-utilized Pools of Talent

Background.—In most of the fields of systematic biology, minority researchers are rare. This also has been true for women, at least at the highest professional levels, although corrections are slowly taking place. With the rapid decline of the environment in developing countries, where most biodiversity is located, training of students from those areas is becoming crucial.

Recommendation.—Increase funds available for researchers from these under-utilized groups, and earmark those funds specifically for grants that include these individuals. Encourage support, as research assistants, of foreign students who wish to train or pursue advanced degrees in this country. Fund workshops to solicit advice from under-utilized groups on how best to accomplish these goals.

2. The Unique Role of NSF Funding in Systematic Biology

Background.—Because of the primarily non-applied nature of our research, we rely heavily on NSF for funding. Some systematic projects (particularly those on economically important organisms) can utilize funding from other government agencies (e.g., Dept. of Agriculture in entomology) or private industry (the petroleum industry for invertebrate paleontology), but the bulk of our research funding is supplied by NSF. Almost all theoretical work is NSF funded. Adoption by systematists of new technologies, such as molecular biology, computer-based imaging, and high speed video systems benefits the field but greatly increases monetary costs. There are no obvious other sources of those funds for most systematists. Systematic collections are a cooperative effort between host

institutions and NSF. Because they serve a national and international constituency, NSF support is appropriate and necessary.

Recommendation.—NSF must recognize that it is the most important source of money for systematics and evolutionary biology. If the field is to grow, both intellectually and in applied pursuits, budgets will have to be expanded to fund more researchers and new technologies. A serious commitment to biodiversity research will demand more systematists with access to more resources.

3. *The Role of Systematics in Other BSR Programs*

Background.—The role of systematics and systematists in the funding process of related programs (population biology, ecosystems, etc.) should be expanded. As we have noted above, we believe that good systematics is fundamental to many areas of organismal biology. Problems (errors) in identification, statements of relationship, or phylogenetic methodology can have a profound negative influence on the results of these studies. Not uncommonly, biologists in these disciplines lack an explicit background in systematics. Therefore, reviewers and panelists may not be in a position to adequately judge the systematic component of research proposals.

Recommendation.—Either as reviewers, or as direct additions to their panels or through a more extensive joint meeting of panels, systematists should be more thoroughly a part of the review process in those programs where systematics is a "hidden" part of the project.

4. *Multi-disciplinary / Multi-institutional Grants*

Background.—Although NSF accepts and encourages interdisciplinary grants, such proposals face hurdles that single investigator grants do not. Problems include format, division of responsibility, reporting requirements, institutional requirements, and logistics.

Recommendation.—NSF should provide a set of clear, concise guidelines appropriate to such grants. It may be entirely appropriate that a different format for submission would be suitable for such proposals. Ways of incorporating participation of scientists and institutions in developing countries need to be simplified. Unless budgets are increased, large interdisciplinary, multi-institutional grants may not be feasible.

5. *The Need for Attention to Theory*

Background.—Modern systematics relies significantly on a variety of quantitative, frequently computer-based, methodologies. We currently rely on the energy and intellectual fervor of a small number of researchers with interests in algorithm and software development. Unfortunately, the productivity of these endeavors is not easily comparable with more traditional research programs and as such many biologists are reluctant to invest significant energy in this area.

Recommendation.—Special attention should be given to proposals for research into systematic methods and their assumptions, with particular priority given to making new, well documented, methods more widely available to the research community.

6. *The Impact of Current BBS and BSR Organization Structure on Systematics*

Background.—The Systematic Biology Program is strongly identified as supporting both multi-species comparative biology and research oriented toward understanding the origination of taxa. The breadth of its mission makes the Program the primary funding source for alpha-level and revisionary systematics, comparative functional morphology, biogeography, and many other areas of evolutionary research. Many of these areas are vital to understanding biodiversity.

Recommendation.—NSF should keep the Systematic Biology Program dedicated to systematic studies, both broadly and narrowly construed. Significant new funds earmarked for biodiversity studies should be channeled to the Program to support appropriate research projects.

Prepared by Julian Humphries, William Fink, and Joel Cracraft.

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Improving the Stability of Names: Needs and Options (Kew, 20-22 February 1991)

In the December 1990 issue of this journal, Jay M. Savage gave a detailed report of the new trends in zoological nomenclature, as they emerged during the Fourth International Congress of Systematic and Evolutionary Biology (ICSEB IV) at College Park, Maryland. In his report, Savage especially stressed the official provisions adopted by the International Commission on Zoological Nomenclature (ICZN) in order "to promote stability and universality" of names in a way he described as "revolutionary."

From Savage's report it was not easy to place the new trends of zoological nomenclature in a wider context, especially to compare them with action taken by other segments of the biological community interested in the names of living organisms. However, it is widely known that a primacy of use over strict priority, as a working foundation for what is hoped to be a stable nomenclature, has been incorporated for a considerable period in the International Code for the Nomenclature of Bacteria. Those provisions