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## COMMENTARY

[“Commentary” is a section of *Quaest. Ent.* that will appear from time to time, and will contain expressions of opinions about general items, controversial or otherwise, that ought to be of interest to many of our readers. These contributions will not be refereed because they are intended to be free expressions of opinion. Changes by the Editor might be made to the form of presentation, but not to its substance. Remarks that are deliberately abusive or insulting will not be published. Rebuttals to previously expressed views will be considered, but the journal is under no obligation to publish them.

The Editor]

UNIVERSITY TRAINING OF SYSTEMATIC ENTOMOLOGISTS<sup>1</sup>

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Presented here are thoughts about the training of systematic entomologists, based on experience gained during 30 years of work with graduate students, on my own experience as a graduate student, and on discussions with graduate students and colleagues including those who took degrees with me. I do not have anything original to add to what is probably common knowledge, but I think it is worthwhile at least to review our common knowledge as background for other considerations.

The words “training” and “university” used in near juxtaposition in the title of this presentation may seem to some at least inappropriate if not offensive. Universities are supposed to deal with education, while trade schools and the like are supposed to provide training. Training is development of professional skills by means of a rigorous and exact course of study which results in the student’s appropriate response to particular situations likely to be met during the subsequent years of employment. Education, on the other hand, develops in an individual the ability to think broadly, and to bring to bear on complex problems novel actions that will lead to appropriate solutions. As well, an educated person is expected to develop new concepts and to perceive previously unsuspected problems, the

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solutions of which have generally interesting and significant future consequences.

If this expectation is to be realized, any person who hopes to become educated must be trained in order to acquire mastery of the basic tools of some field of knowledge, with that field providing both focus and background for study and contemplation. Indeed, a legitimate part of the educational process is training, and I will address my remarks to this aspect of a university program in relation to systematic entomology. During the period of training, ample opportunity ought to be provided for professors to help with development of an appropriate perspective for an educated person to have.

I concentrate my remarks at the level of graduate study, that is, formal university work following the bachelor's level. I comment only briefly about undergraduate and post-doctoral study.

#### UNDERGRADUATE STUDY

During the undergraduate years, those who have indicated interest in insect systematics must be encouraged to seek a broad knowledge of organismic diversity; it is not enough that a person come to know in great detail a single taxon of insects of family rank or less. There has to be a context or general frame of reference within which is developed the detailed knowledge of a special group. A certain amount of knowledge of diversity can be gained in courses, but other opportunities should be provided— such as field work during summers, and museum work that will allow a beginning student to have experience in insect identification and curation of an institutional collection. A beginning student should also be encouraged to develop a personal collection.

Because of the relatively advanced knowledge about classification and evolution of vertebrates, those in insect systematics should be encouraged to study the Chordata, even though this phylum exhibits relatively slight structural divergence, has rather few species, and its classification is burdened with many paraphyletic groups.

Although would-be systematic entomologists must gain a broad knowledge of organismic diversity, they must also know something about other aspects of entomology, such as functional morphology, embryology, physiology, ecology, biochemistry, and applied entomology. This background is required because systematic work has implications for all of these other areas, and as well, some problems encountered in the latter offer opportunities for taxonomic investigation. If, because of other constraints in the study program, an undergraduate is unable to devote much time to other aspects of entomology, these should become part of the graduate program.

## GRADUATE STUDY

**Degrees**

The doctoral degree is the normal terminal degree for at least North American systematists. A Master's degree is optional, but I regard the preparation of a Master's thesis of substantial value in enhancing the quality of the doctoral dissertation because of the experience gained in scientific writing, and in approaching a taxonomic problem. Consequently, I believe that those who wish to do graduate work in systematic entomology should begin in a Master's program.

**Graduate Students: Attributes and Predilections**

Who ought to be encouraged to enter the field of insect systematics? The answer depends upon the nature of the work to be done. In turn, this is determined by the general state of knowledge in the field. For example, the physical sciences are such that individuals are required who are experimentally inclined and who have the ability to think and to express their thoughts in terms of mathematics. Those without such attributes would be well advised to seek other forms of endeavor.

At this time, a person who would study taxonomic aspects of extant vertebrates must be willing to work at a level requiring routine use of techniques of cytology, genetics, electrophoresis, DNA analysis, and advanced statistics, including multivariate analysis. This is because previous generations of workers succeeded in making known and analyzing well a mass of information about most vertebrate taxa. Further progress is thus dependent upon exploitation of character systems requiring sophisticated methods for study, or upon reanalyzing the more traditionally used features in new ways. In fact, so much detailed information is now available for many groups of vertebrates that further progress in working out their relationships might be dependent upon not single individuals but rather groups of cooperating specialists, each specialist contributing his own special knowledge to the problem or taxon under study.

For systematic entomology, the state of knowledge of insect taxa ranges from rudimentary to detailed and highly complex. If progress is to be made on a broad front, a range of individuals must be sought whose abilities and inclinations encompass collectively the types of taxonomic problems encountered.

Most taxonomic work on insects must still be concerned with descriptions of new extant taxa that are known from a few dead adults and that are characterized in terms of external features of body sclerites and appendages. Those who would study such taxa must have a predilection for comparative morphology, and must be mentally capable of dealing with the uncertainties inherent in conclusions based on limited material. They must be prepared also to deal with bibliographic problems inherent in finding and assembling references to names and descriptions published in centuries past, for many supraspecific insect taxa have not been adequately catalogued, and their type species are unknown or have not been designated.

On the other hand, to deal with drosophilids, various groups of biting flies, and butterflies, individuals are required who are competent at biochemical studies, or mathematical analysis, or sophisticated physiological and behavioral experiments. Such individuals might be unsuited for working with taxa known from few specimens, and whose geographical ranges are best expressed in terms of type localities!

Individuals are required who find satisfaction in preparation of faunal works—that is, elucidating insect taxa that occupy a geographically defined portion of the world, such as the pentatomids of Canada, or the peloridiids of Tierra del Fuego. Undertaking such studies might have at most limited appeal for those seeking broad understanding of phylogenetic relationships, but the resulting publications are very useful to residents of the areas concerned, and can be highly stimulating to development of interest in the taxon by local amateur naturalists.

Individuals are required who find satisfaction in achieving mastery of bibliographical techniques, and who are inclined to devote substantial portions of their working careers to cataloging and clarifying bibliographical details. Preparation of catalogs of type species and investigations of nomenclatorial problems also come within the purview of those with a bibliographical bent.

Probably the very best individuals can find satisfaction in working at all levels of the spectrum of sophistication indicated above, using techniques from the most rudimentary to the most complex. Many individuals, however, have more limited talent, or inclinations that suit them to work at only a few levels, whether toward the simple or the sophisticated end of the spectrum.

Can persons be easily and accurately identified who ought to be encouraged to become systematic entomologists? I do not think so. About the best that can be done is to keep in mind the broad range of interests and inclinations that can be used in systematic entomology, and to give those persons who express deep interest the opportunity to show what they can do.

### **Program of Graduate Study**

Regardless of the predilections of would-be insect systematists, all ought to have a basic fund of common knowledge and experience. I suggest the following:

1. *Scientific reasoning, and history and philosophy of science.*— The need for knowledge of these areas is not confined to systematists. For their work in history, systematists may emphasize study of the development of their own field.

As a part of the study of philosophy of systematics, graduate students should be encouraged to ponder the value of systematic entomology to themselves, biology, science, and society at large, for they will be faced with such an issue many times during their lives. If they develop a sense of the value of systematics, they will be able to answer criticisms put to them by individuals

who do not understand the field.

2. *Literature of systematic biology.*— A systematist must be able to design and conduct efficient literature searches in conjunction with research projects. This requires knowledge of libraries and bibliographic sources in general, and as well, specific sources for information about particular taxa.

It is also important that a systematist pay attention to publications about taxa other than those of immediate interest. Techniques and ideas for analysis and synthesis that are standard for workers in some taxa might be of value in other taxa as well, but workers in the latter groups will not know this if they do not read the literature about the former groups.

3. *Principles and methods of automated data processing.*— These should be studied, for such systems are of substantial and increasing importance to systematists, who must deal quickly and effectively with extensive quantities of information. Included are bibliographies and other indexes to scientific literature, many of which are automated.
4. *Systematic theory.*— Included are: processes of speciation; principles and methods of phylogenetic reconstruction; and principles and methods of formal classification. The notion that taxa are limited and linked by systems of relationships (ontogenetic, tokogenetic, and phylogenetic) must be appreciated—even though workers on many groups might never have the opportunity to use directly such an idea.
5. *Insect morphology and taxonomic diversity.*— A graduate student in systematic entomology must have formal training in these areas if the appropriate courses were not taken during the undergraduate years. These areas of study are basic to all other work in systematic entomology.
6. *Character systems.*— Graduate students in systematic entomology should have the opportunity to become familiar with a wide range of character systems, and the process of data gathering and problems of interpretation associated with each system. Even though such systems as allozymes and cytological features may not be used subsequently by a given individual, having the opportunity to study them provides a broadened perspective and the ability to interpret more readily publications about such systems.
7. *Applied entomology.*— Because of the general importance of agricultural, stored products, urban, and medical entomology to the field of entomology in general, and because many taxonomically important and interesting discoveries emerge from studies of economically important insects, a systematic entomologist ought to be well informed about applied entomology. If suitable courses were not taken during the undergraduate years, they ought to be included in the graduate program.
8. *The temporal dimension.*— Study of palaeontology (particularly vertebrate) ought to be included in the curriculum, so that a developing systematist can get first-hand knowledge of the basis of statements about evolution of structural

features inferred from temporally arranged fossil material.

From the same perspective, a graduate student in systematic entomology ought to be encouraged to seek contacts with specialists in the Quaternary Period, for this geological age is closest to the Present, and is the past age about which most can be learned. One's horizons are widened appreciably when confronted with the ever-increasingly detailed evidence for striking changes in geographical ranges of extant taxa, and in community composition during and after the Pleistocene. This knowledge is very important in the interpretive phase of systematic work.

9. *The spatial dimension.*— The principles of geographical distribution of organisms are vital in understanding taxa and their histories and relationships. Graduate students should attempt to gain a mastery of zoogeography, and to apply this knowledge in their own work.
10. *Zoological nomenclature.*— Principles and procedures followed for the naming of taxa are important components of taxonomic work, and especially so for the many insect taxa that are so inadequately known. Nomenclature may seem to be an anachronistic aspect of biology, but until most species have been described and the types of genus-group and suprageneric taxa have been fixed, systematists must concern themselves about the rules applied to naming animals.
11. *Field work.*— A graduate student in systematic entomology must think of the organisms that he studies as parts of living systems. One gains the necessary appreciation through field work. Also, observations made in the field provide a range of characters whose states are not observable in preserved material.
12. *Curatorial work.*— Graduate students should be exposed to curatorial work, so that they become familiar with the problems and methods of collections management. They should have the opportunity to do such work, both in their own institutions and elsewhere. This type of experience may be gained through development of cooperative programs with those public institutions that house extensive insect collections. A graduate student might thus spend part of his time in, say, the national museum of his country. Such an arrangement would provide also other educational opportunities.
13. *Communication.*— A graduate student in systematic entomology should have the opportunity to learn and practice the skills of oral and written presentations. This involves seminars, talks at local and national meetings of entomological societies, and preparation of short papers and reports.

As the general background is acquired, a graduate student becomes familiar with the intricacies of a particular taxon. The knowledge thus gained provides the basis for a thesis. The study group should be neither too diverse nor too restricted. The less diverse the group, the greater should be the depth of analysis, and *vice versa*.

Because of the level of commitment and effort required to produce good taxonomic work, graduate students should be encouraged to choose their own study groups. Generally, this is the normal course of events, for most of those who go into systematic work have an idea of what they want to do before beginning a graduate program.

#### **Graduate Training in Relation to Employment**

Only rarely does a graduate student receive the opportunity to spend his career studying the taxon on which the thesis was based. Consequently, to be employable, most freshly graduated insect systematists have had to shift attention from the taxon of choice on which the doctoral thesis was based, to the taxon selected by the employer. The graduate training received should make it possible for this shift to be made relatively painlessly.

#### POST-DOCTORAL STUDY

Because of demands of employers, a recently employed systematist has at best only limited time for further development of his special professional interests. For example, a systematist employed by a university department is likely to find much of the first few years occupied with preparation and delivery of undergraduate-level courses, some of which may be related only remotely to systematic work. Little time is available for research, and in effect, the development of a career in systematics can be disrupted thoroughly. At some stages of development, such disruption can inhibit seriously further development. However, if a satisfactory stage has been attained, the disruption need not have serious effects. Such a stage would be characterized by publication of the doctoral dissertation and development of a long-term research program.

This goal of optimal development of professional interests could be attained with a two-year post-doctoral program. During this time, a systematist would also have the opportunity to work with other systematists, and to learn methods that were not learned during the doctoral program. As pointed out elsewhere (Steussey and Thompson, 1981), another advantage of the post-doctoral program is that it gives an individual some advantage in obtaining employment, or at least places him on the same footing with other applicants who have had post-doctoral experience.

#### CONCLUDING STATEMENT

I have addressed the topic of what sort of training a systematic entomologist ought to have in the course of a university program. I believe that training of this sort will serve systematic entomology well for the foreseeable future because I believe that the problems of the field are not going to change very much from what they have been (Slater, 1981). If so, students exposed to the elements of the program



that I have outlined in cursory fashion will be capable of carrying out valuable systematic work for the length of their careers—provided, of course, that they continue to study broadly, and that they can find employment related to that program.

Following are comments about several important items that are peripheral to the main theme of this presentation, but that ought to be noted in the context of training of systematic entomologists.

1. *Further training of professional systematic entomologists.*— If a systematist's interests change, or if his job requires a change of taxa on which he works, an intense short course offered by a specialist on the taxa in question could be very helpful as a first step in re-direction.
2. *Training of systematic entomologists of economically under-privileged nations.*— I affirm the striking need for more systematists who are residents of tropical nations. Although many such nations are impoverished economically, they support astounding biotic wealth. It is clearly desirable to develop programs through the community of nations designed to encourage the training of systematists who are residents of such countries.
3. *Systematic entomology and the tropics.*— As Steussey and Thompson (1981: 7-18) have pointed out so eloquently, the need is urgent to increase research on the tropical biota. For entomologists, the inordinate diversity of the tropical insect fauna stands as a major challenge, but those from northern countries who would respond require special training for work in tropical environments and habitats. To this end, it seems desirable to encourage existing tropical-based research establishments, such as the Organization of Tropical Studies and the Smithsonian Tropical Research Institute to increase their capabilities of training systematic entomologists.

Finally, I re-affirm my belief that systematics is an intellectually satisfying field of biology, that it is essential for the continued development of science, and that it is worthy of public support and of university degree programs. This importance is acknowledged in the institutions of higher learning of some nations, but in others there is scarcely any opportunity for a would-be systematist to obtain the training required to become a professional in the field.

In all countries, systematics is underfunded, in spite of its importance. This shortcoming must be corrected, and achieving the necessary correction ought to be the goal of at least the senior members of the community of systematic biologists. If support for research in systematics continues to decline, there will be no need to think about training systematic entomologists, for there will be no career opportunities for such individuals.

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