SYSTEMATICS AND ENTOMOLOGY: INTRODUCTION

GEORGE E. BALL
Department of Entomology, University of Alberta, Edmonton, Alberta, Canada T6G 2E3

and H.V. DANKS
Biological Survey of Canada (Terrestrial Arthropods), Canadian Museum of Nature, PO Box 3443, Station D, Ottawa, Ontario, Canada K1P 6P4

Many more species of insects are living than have been described. The dearth of knowledge about insect diversity hinders acquisition of knowledge about the ecological support systems of the planet, which are being destroyed through species extinction and other forms of biological degradation (Soulé 1991). Therefore, it is timely for systematists to explain again the contributions that they make through their work, and to reassert the importance of this sphere of activity.

This volume emphasizes the value of systematics from a variety of perspectives. The papers included here demonstrate to the community of scientists in general, and to the entomological community in particular, the benefits of studies in systematics.

The volume is based on a symposium, organized by the editors, that was held under the auspices of the Biological Survey of Canada (Terrestrial Arthropods) at the joint annual meeting of the Entomological Society of Canada and the Entomological Society of Alberta on 8 October 1990. A geographical component of that symposium and of the volume that resulted is the source of the contributors: all are Canadian and have done most of their work in Canada; collectively, the papers illustrate the breadth of research in systematic entomology conducted in this country. Although most of the papers are based on study of insects in Canada, they focus on problems that transcend national boundaries. They reinforce the importance of work in systematics and the requirement that it be supported.

Current Problems

It is a paradox that, as awareness of biological diversity and concern for the environment increase as an item of public interest (Koshland 1991: 717; Ehrlich and Wilson 1991), support for systematics is declining. If enough were known about biodiversity, such a paradox simply could be noted in passing as an interesting sociological phenomenon to be studied by science historians, and no other redress would be required.

To informed scientists outside the biological community, and to others who are not biologists, it must seem strange that at present such a central field of biology as systematics is massively underfunded, and such support that it has received in the past is being reduced. Traditionally, systematists have been supported through publicly funded positions in institutions of higher learning, in governments of various levels, and in museums (either public or privately endowed). This support is being decreased. In Canadian universities, for example, study of systematics as a biological discipline is waning. As systematists retire, they are being replaced by other types of biologists. Government positions in systematics are disappearing. Indeed, an entire Canadian institution, recognized worldwide for its scientists and their work, has ceased to exist as a separate entity (Hunter 1991).

Very large numbers of species remain unknown (Stork 1988). Furthermore, the great bulk of these unknowns are invertebrates, and indeed, terrestrial arthropods. Thus, if there were a logical structure to human society, one could predict that systematic entomology would be flourishing, students would be flocking to programs in systematic entomology, positions in systematics would be opening in public institutions, and museums would be receiving unprecedented support for their research activities.
Table 1. Components of systematics and types of systematists

<table>
<thead>
<tr>
<th>Component of systematics</th>
<th>Type of systematist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biosystematics</td>
<td></td>
</tr>
<tr>
<td>Speciation</td>
<td>Speciationist</td>
</tr>
<tr>
<td>Phylogeny</td>
<td>Phylogenist</td>
</tr>
<tr>
<td>Taxonomy</td>
<td>Taxonomist</td>
</tr>
<tr>
<td>Classification</td>
<td></td>
</tr>
<tr>
<td>Nomenclature</td>
<td></td>
</tr>
</tbody>
</table>

These things are not happening. Even a book entitled "Biodiversity" (Wilson and Peter 1988) scarcely mentions systematics. Therefore, it is especially important for systematic entomologists to make known this situation, and to explain, as in this volume, how their work impinges upon entomology in particular and upon biology in general.

**Definitions and Activities**

The following definitions are offered to ensure understanding. **Entomology** is a taxon-based science, delimited by the limits of taxa—principally the Insecta or Hexapoda, but for practical considerations, extended to include their relatives among the terrestrial arthropods (i.e. most extant chelicerates, and myriapods). Thus, we consider entomology as the study of terrestrial arthropods, with the goal to achieve understanding of all aspects of these creatures.

Entomology is a subset of the more inclusive science of biology, the study of life. In an important sense, not always appreciated, biology is also taxon-based, its scope delimited by the limits of the unranked taxon "Life," that includes all taxa that are living or that have lived. A **taxon** is "a grouping of organisms given a proper name, or a grouping that could be given a proper name but is not named as a matter of convention" (Wiley 1981: 6).

**Systematics** is a concept- or idea-based science concerned with principles and functions used to organize knowledge in general. For biology, systematics is defined as the study of diversity (Simpson 1961: 7) or "biodiversity" [a term coined by W.G. Rosen (Wilson 1988: vii)]. The goal of systematics is to understand species, what they are and how they are related, to reflect such relationships in a formal classification, and to provide distinctive names for the groups recognized. "Systematics permits basic identification, makes information available, assembles information from a comparative perspective and thus allows synthesis, and generates and stimulates ideas and hypotheses applicable to other fields" (Danks 1988: 288).

Systematics is compartmentalized because not all systematists carry out or are even interested in all of the facets and procedures of the field. To identify and delimit the compartments, various terms are used (Table 1), as explained by Ball (1982: 5), based in part on Ross (1974: 12). Small (1989) discusses in detail the history of use of these terms.

The use of **biosystematics** to delimit the activities of those who study speciation and phylogeny is controversial (Small 1989: 346–347). The word, originally "biosystemat-" was proposed to recognize a distinction between systematic botanists who restricted their studies to herbarium specimens ("taxonomists") and those who employed character systems for which knowledge of living or recently preserved specimens was required, such as chromosomes, flowering times, pollination systems, and so on (the "biosystematists") (Camp and Gilly 1943). Ross (1974) generalized the term biosystematics by extending its application from only a set of methods (Solbrig 1970) to a field of endeavor in which any appropriate methods could be used. As well, that field of endeavor may be designated "evolutionary systematics" or "analytical taxonomy" (Humphries and Parenti 1986: 12). As used here, biosystematics is the body of general theory that underlies phylogenetic
analysis, and is the equivalent of the term “systematics” as restricted by Erwin (1991: 751), Crowson (1970: 19), and Wheeler (1990: 1033).

The Value of Classification

The products of activity in systematics that are used most widely in the biological community are classifications. Biological classifications are hierarchical, for a variety of reasons (Sokal and Sneath 1963: 17, 171). Hennig (1966: 15–21) and Wiley (1989: 299) emphasize that evolutionary relationships, which by their nature are hierarchical, provide a logical basis for classification. Griffiths (1974: 85) argues that “ordering according to systematic relations may be called systematization,” with the term classification being restricted to ordering of objects into classes. Such a distinction, while useful, has not been adopted generally.

Although phylogenetic relationships provide a sensible, natural basis for ordering organisms in a hierarchical system of classification, other bases might be used. For example, classifications are made by pragmatists, nominalists, special creationists, pheneticists, and transformed cladists. If such classifications were unusable, we could simply exclude, by definition, their work from systematics. However, useful classifications are produced using bases other than phylogenetic relationships for delimitation of taxa, and thus such work is included in the purview of systematics. Nonetheless, we regard phylogenetic classification as the ultimate stage in the development of knowledge of taxa, as indicated below.

The Progress of Knowledge

Under many circumstances, there is good reason to recognize and classify taxa in the absence of ability to postulate their phylogenetic relationships, i.e. without the constraints imposed by evolutionary theory (Wheeler 1990: 1041). For example, we might produce quickly a taxonomic treatment of the biota of some large, remote, lowland tropical area, without regard for the fundamental relationships that underlie similarities and differences in routinely prepared biological material (Janzen 1991). Biologists could use such a taxonomic treatment to extend knowledge of that biota in a variety of directions, or to promote its conservation. Later, the treatment could be refined to reflect an evolutionary underpinning.

One might wish that works devoted to elucidation of floras and faunas would come after the definitive evolutionary treatments. A progression of this sort could be achieved if the affairs and activities of man were organized logically. In the absence of such overriding organization, operations are carried out in a sequence determined by expediency and human predilection.

Indeed, we develop classifications through episodic improvements brought about by increases in amount and quality of material for study, use of additional characters and character systems, and increasingly sophisticated methods of analysis (Darlington 1971; Ball 1982; Arnold 1991: 26). Mayr et al. (1953: 19) recognized three episodes, designated sequentially “alpha,” “beta,” and “gamma” stages. Darlington (1962: 328–329) used a similar three-stage sequence, each stage designated less pretentiously “first,” “second,” and “third.” A somewhat modified system that recognizes three stages, giving equal emphasis to the between-stage distinctions and the activities that extend through all three stages, is shown in Table 2.

The pattern of development of analysis and knowledge of taxa is indicated in generalized fashion in Figure 1, in which taxa are represented by lines that are extended in various directions. The diagram indicates that most taxa are in the first stage of analysis. Terrestrial arthropods are concentrated in the first stage. Most vertebrate taxa are in the second and third stages, with most fish groups in the second stage, and many tetrapod groups in the third stage. The figure shows also that some taxa are subjected to increasingly complex and sophisticated analysis through time, which leads to increase in knowledge
and understanding. Such improvements are made possible by increased numbers and sizes of samples, better coverage of attributes through study of features not used previously, and more detailed understanding of relationships.

An example of the development of knowledge in this way, through all three stages, is shown in Figure 2, which represents in simplified form progress in systematic analysis of North American butterflies of the *Papilio machaon* group. Taxonomic work in the 19th century provided descriptions of most of the taxa recognized currently. As Sperling (1987: 203–204) pointed out, it was clear by the late 19th century that more names had been proposed than were required to reflect accurately the taxonomic components of this group. Rothschild and Jordan (1906), in their monumental revision of the Papilionidae (a stage 2 analysis), used more material than had been available to previous workers and, with an essentially modern notion of species, clarified markedly the understanding of the species of the *P. machaon* group, principally through analysis of structural features (including color pattern).

Problems remaining about species limits and species relationships could not be resolved using only structural features. Sperling (1986, 1987, 1993) extended analysis of the *P. machaon* group to stage 3, using abundant material, and studying variation in life history, food plants, structural features of larvae, and molecular features studied by means of electrophoresis and analysis of DNA sequences. Thus, advances in understanding the *P. machaon* group have featured an expanded base of study material and character systems, and improved methods of analysis. Darlington (1971: 353) emphasized also the importance of availability of time and opportunities to carry out the required studies. Indeed, Sperling’s carefully planned and well executed work on the *P. machaon* group has extended over many years of essentially uninterrupted study.

It is important to realize three things about taxa that have been recognized and described: first, knowledge of most of them is relatively rudimentary; second, learning about them is a continuing process; and third, the more sophisticated and complete this knowledge is, the more useful it becomes. For example, Danks (1988: 284) cites references to publications recording the importance of taxonomy to discovery of organisms for use in biological control. Conversely, inadequate information about or inadequate attention to systematic aspects of taxa can be markedly disadvantageous to biological practice (Danks 1988: 289, table 2).

We emphasize also that, although systematic entomologists during the past two centuries have recognized and described most of the major terrestrial arthropod lineages

<table>
<thead>
<tr>
<th>Stage of systematic analysis</th>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (1–3) Select features for analysis, analyze similarities and differences, form and rank groups, provide names.</td>
<td></td>
</tr>
<tr>
<td>1 Pragmatic-phenetic type-based revisionary work, element drop species descriptions based on structural features.</td>
<td></td>
</tr>
<tr>
<td>2 Comprehensive revisions, currently with at least an implicit theoretical base in evolution or phenetics, detailed species descriptions based on structural features.</td>
<td></td>
</tr>
<tr>
<td>3 Rigorous tests of Stage 2 phylogenetic hypotheses (Neontology and Palaeontology), use of genetic techniques and ecology and ethology (Neontology and Palaeontology), origin and extinction rates (Palaeontology only), patterns and rates of differentiation of lineages, etc. (Palaeontology only).</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 1. Hypothetical pattern of development of knowledge of taxa. The vertical axis represents time, and is divided into three arbitrary periods, A, B, and C. The horizontal axis is divided into the three stages of systematic analysis, 1, 2, and 3. Each vertical line represents a supraspecific taxon, extending from its date of original description to the present. Horizontal lines connecting vertical lines indicate continuity of the latter from one stage to another. Horizontal arrows indicate shifts of knowledge of taxa from one stage to another. The diagonal arrow indicates the general trend in increasing knowledge of supraspecific taxa.

(classes, orders, and families), most of the less inclusive lineages (genera and species) have not been described, much less classified (Wilson 1985; Erwin 1982).

Description of the elementary units is important, but sense is made of such units through classification, and the continuum between description and classification is the standard intellectual fare of taxonomists. Classification continues long after the basic units have been described, producing changes based on improved understanding of relationships.

Through comparison of preserved specimens, systematists discover distinctive patterns of structural features that lead to initial classifications. Information about where the specimens were collected is recorded routinely, and thus information on geography and habitat (or geological horizon for fossilized material) is readily available. Analysis of such distributional information then becomes the subject of other fields of endeavor, such as historical and ecological biogeography. In turn, systematists use patterns discovered by biogeographers to help infer evolutionary relationships of taxa.

Information about host associations is noted more-or-less routinely for phytophages and insects parasitic on other animals. Patterns of association visible from such information, with inferences about the functions of special forms of structure, permit further inferences about the general biological processes that have led to development of the observed and inferred patterns. Thus, specific taxonomic information can be understood in general terms, and at the same time adds to the general store of information about life.

The comparative method, which is basic to taxonomic work, is not the exclusive domain of taxonomy. Comparisons of way of life of related living organisms is a valuable
Fig. 2. Historical development of systematic analysis of the Papilio machaon species group in North America.

source of information about adaptation, and in turn, the adaptive patterns discovered by morphologists, ethologists, physiologists, and ecologists provide information of great value for understanding relationships. Taxonomists incorporate such understanding in their descriptions and organization of biodiversity.
Conclusions

Information about taxa provided by systematists is the basis for making biological knowledge accessible and for understanding biodiversity. The interplay between systematics (with its focus on biodiversity) and other aspects of biology, particularly patterns and processes of distribution and adaptation, is one of “reciprocal illumination” (Hennig 1966: 206): improvements achieved in a traditionally non-systematic field of biological endeavor are captured and made use of by systematists. Conversely, non-systematists are able to use advantage the improved classification and ideas about relationships that the systematists generate.

Knowledge achieved through the integrating work of systematists has important practical applications in the humanities, and in management of populations of organisms designated in human terms as harmful or beneficial (Danks 1988: 283). Such interrelations among the fields of basic biology and between basic and applied biology are the focus of this symposium, and are explained and illustrated in the following contributions.

References


(Date received: 22 March 1992; date accepted: 12 May 1992)