FORUM

Phylogeny, Systematics, and Practical Entomology: The Heteroptera (Hemiptera)[1]

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Filogenia, Sistemática e Entomologia Prática: Heteroptera (Hemiptera)

RESUMO - A aplicação do trabalho em sistemática e filogenética pode ter muitos efeitos práticos na entomologia aplicada. A filogenia é o estudo das relações evolucionárias dos organismos; a sistemática usa os resultados da filogenia para contrair sistemas de classificação. Se alguém sabe algo sobre as relações filogenéticas e sistemáticas de uma praga de uma cultura, então ele sabe os parentes da praga ou cultura, e pode predizer o que poderão fazer no futuro. Tal conhecimento e predições são especialmente importantes em países em desenvolvimento, os quais estão diversificando sua agricultura. Insetos que se alimentam de plantas selvagens podem se tornar pragas quando os parentes destas plantas são introduzidas como culturas. Similarmente, nesses países, parentes selvagens de pragas de outros locais, podem eles tornarem-se pragas quando a mesma cultura é introduzida. Habilidade de fazer tais predições permite aos países estarem preparados para combater pragas antes que elas tomem este status. Exemplos de tais predições de heterópteros para as culturas no Brasil incluem: certos Blissidae (pragas do arroz e da cana de açúcar na Ásia), certos Alydidae (pragas de legumes na Ásia e agora da soja no Brasil); também alguns triatomíneos Reduviidae (vetores da doença de Chagas na Região Neotropical, potencialmente transmissores da doença de Chagas na Índia). Em adição, o conhecimento da filogenia e da sistemática pode permitir o controle de percevejos do gêneros *Lygus*, um grupo de pragas da Região Holártica (Miridae).

PALAVRAS-CHAVE: Insecta, hemíperos, taxonomia, entomologia aplicada.

ABSTRACT - The application of systematics and phylogenetic work can have very practical effects on applied entomology. Phylogeny is the study of the evolutionary relationships of organisms; systematics uses the results of phylogeny to construct systems of classification. If one knows something about the

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[1] This paper is expanded from a talk I gave at the XVII Congresso Brasileiro de Entomologia, in August, 1998. In rewriting it for publication, I have retained some of the informality of the spoken presentation. I hope doing so makes the paper more accessible and more interesting to a wider audience.

phylogenetic and systematic relationships of a pest or a crop, then one knows the wild relatives of pest or crop, and can predict what either might do in the future. Such knowledge and predictions are especially important in developing countries which are now diversifying their agriculture. Insects now feeding on wild plants may become pests when relatives of those plants are introduced as crops. Similarly, wild relatives in these countries of pests elsewhere, may themselves become pests when the same crop is introduced. The ability to make such predictions allows countries to be prepared for pests before they actually become pests. Heteropteran examples of such predictions for Brazilian crops are: certain Blissidae (pests of rice and sugarcane in Asia), certain Alydidae (pests of legumes in Asia, and of soybean now in Brazil); also some triatomine Reduviidae (vectors of Chagas' disease in the neotropics, potentially of Chagas' disease in India). In addition, knowledge of phylogeny and systematics may allow one to control *lygus* bugs, a Holarctic group of pests (Miridae).

KEY WORDS: Insecta, hemipterans, taxonomy, applied entomology.

For many years the study of both phylogeny and systematics was considered (and by many is still considered) a rather esoteric matter: Perhaps of interest to a few, but of no greater practical value than the study of fugal design in Brahms, or the influences on the novels of Dickens. (Was Brahms more deeply influenced by Bach or by Handel [Brahms was studying Handel when Brahms died].) (Was Smollett's "The Expedition of Humphrey Clinker" a greater influence on "The Posthumous Papers of the Pickwick Club" [see Saintsbury 1895] than was Goldsmith's "The Vicar of Wakefield"? Surely it is of interest, if not of practical interest, to note the similarities among the protagonists of these novels: Matthew Bramble, Samuel Pickwick, and the Rev. Primrose; and to realize the creator of the second was well acquainted with the first and third.)

Many people would argue that of even narrower interest is the study of evolutionary relationships among living things (except among humans): And so—to take an example not at all at random—the phylogenetic relationships of the subfamilies of Reduviidae might fascinate a few people here and there, but surely these relationships cannot have any practical value. As we shall see, this idea is dangerously false.

And, as I hope also to show, we can never know what other evolutionary relationships among insects may prove to have great practical importance. We can never be certain what will prove to be important. After all, as St. Paul wrote to the Hebrews, "Be not forgetful to entertain strangers; for thereby some have entertained angels unawares" (Hebrews 13:2).

Ignorance is not bliss; what we do not know can indeed hurt us.

I am certainly not disparaging knowledge for its own sake. Knowing what influenced Charles Dickens as he wrote, and knowing what the evolutionary relationships are of various organisms—this knowledge is important for its own sake. After all, a feature which sharply distinguishes primates, is curiosity. Satisfying curiosity is satisfying a very basic urge or need of human beings.

However, my topic here is the practical benefits of systematic and phylogenetic work. And my examples are from the hemipteran suborder Heteroptera, the true bugs.

How might a knowledge of systematics and phylogeny help with practical, or applied, entomology? The study of phylogeny yields information on the evolutionary relationships of organisms. Systematics takes that information and organizes it into a system (hence the name). This system is hierarchical—that is, each group is joined with others in a larger group, which in turn is joined with other larger groups into a yet larger group, and so on. All members of any one of these groups share certain characteristics, and so phylogeny and systematics, taken together, allow one to make predictions about organisms once their position in a classification (and thus their evolutionary relationships) are known. Some of these predictions may be of great importance to the practical (applied) entomologist—for example, in ascertaining what insects may become pests when a crop is introduced into a new area, in deciding what methods may most effectively control or manage pests already established in a crop, and in one instance perhaps in determining whether a group of disease vectors presents a threat.

Or, to put the argument more basically and more simply: This is how a knowledge of systematics and phylogeny can help entomologists with practical problems: If we know something about one species of organism, then we can extend that knowledge to its relatives. The closer these relatives are—that is, the more closely related they are phylogenetically,—then the closer and the more exact and the more detailed is the knowledge that we can extend. Two species in the same genus share many characteristics. Two genera in the same family share fewer characteristics, but they share more characteristics than two families in the same order.

Some of this shared information can be useful in practical entomology. But of course before it can be useful, we must know accurately what these systematic and phylogenetic relationships are.

In this paper I shall give two kinds of examples, from Heteroptera. First, three situations where a knowledge of evolutionary relationships may help in controlling pests or preventing serious economic consequences. And second, three examples where a knowledge of evolutionary relationships may help predict what heteropterans might become pests of Brazilian crops.

My first example is highly speculative. It is based on some recent physiological and biochemical work on a serious plant pest, *Lygus lineolaris* (Palisot de Beauvois), known in North America as the tarnished plant bug. This bug is polyphagous and causes major damage to many crops in North America; it has perhaps as broad a host range in North America as the southern green stink bug (*Nezara viridula* (L.)) has worldwide. In 1996, Dickens & Callahan described from the tarnished plant bug a protein which occurs only in the antennae of this species. Later (1998), Dickens & Callahan and others (Dickens *et al*. 1998) showed that this protein occurs in all sexes and stages of the tarnished plant bug, and also in the congener *Lygus hesperus* Knight, itself a pest of several crops in the southwestern United States. This particular protein does not occur in two distantly related heteropterans, one a predacious and the other a phytophagous pentatomid (Dickens *et al*. 1998).

This protein is believed to bind odors, perhaps those from host plants and/or sex phermones. But what these bits of information have to do with systematics and phylogeny?

There are about 51 undisputed species of *Lygus*, in Europe and North America (Schwartz & Foottit 1998; for distribution, see Schaefer 1999). There are also about 135 species in the Old World Tropics, listed as "incertae sedis" in Schuh's Catalog (1995).

Systematics—in this case, the revision by Schwartz & Foottit (1998)—tells us that all these temperate-zone *Lygus* are related. The protein occurs in two *Lygus* species, and perhaps it occurs in all. If the protein can somehow be used in biological control of the pest *Lygus* species in which it occurs (*L. lineolaris* and *L. hesperus*), then perhaps it can be similarly used in control of pest *Lygus* species in which it has not yet been found. The facts that this protein occurs in both *L. lineolaris* and *L. hesperus*, and that these two species are not closely related (see Schwartz & Foottit 1998, Fig. 498), suggest that this protein may indeed occur throughout the genus.

How might it be used? If the protein can be synthesized, it should then be possible to use it, or an analog of it, to disrupt the scent signals that *Lygus* species use either to find host plants or to find mates. If this can be done, it may help control not just the two *Lygus* species, but other pest species in the genus. This possibility of controlling other pest *Lygus* exists for two reasons. First, because systematics tells us that all *Lygus* species are related, and therefore what is true of one species (e.g., this protein) may be true of all.

The second reason is this: This protein occurs in these *Lygus* species, all of which are very general feeders. Yet it does not occur in *N. viridula*, also a very general feeder. This is significant, because it tells us this particular protein may well be restricted to *Lygus*, and is not a protein generally found in polyphagous heteropterans. In other words, the protein is systematically restricted, because it is found in only one systematic group. But it is also phylogenetically restricted, because it is *not* found in a phylogenetically distant—that is, distantly related—group, the Pentatomidae—even though members of this group, like members of the mirid genus *Lygus*, often feed very generally.

Because of these restrictions—systematic and phylogenetic—this protein may prove to be useful in helping to control a group of serious heteropteran pests, species of *Lygus*. Odor-binding proteins occur in other groups of insects, and possibly in all (Dickens *et al*. 1998). They occur in *Lygus*, and doubtless therefore they occur in *N. viridula* as well (although they are of course different in *N. viridula* than in *Lygus*). Once found in *N. viridula*, the odor-binding protein (if that is what it is) may help control the southern green stink bug too.

My second example is very much a Brazilian one. An important pest of soybean throughout Brazil's soybean-growing areas, is a member of the heteropteran family Alydidae, specifically of the subfamily Alydinae (Panizzi 1988). For many years alydines were believed to feed rather generally. But in 1980, a paper appeared whose author had surveyed the literature and found that members of the subfamily Alydinae feed almost exclusively on legumes (Schaefer 1980); a further survey (Schaefer & Mitchell 1983) confirmed this fact.

If one introduces a legume crop into a new area, it is not unexpected that local wild legume-feeders will begin to feed on that crop and, if not controlled, will become a pest on it. This is exactly what happened when soybean was introduced into Brazil: Several feeders on wild legumes turned to soybean, and became pests on this crop: *Euschistus heros* (F.), *Leptoglossus zonatus* (Westwood), *Piezodorus guildinii* (Westwood), and several others; and the southern green stink bug (*N. viridula*), a pest on everything that grows, also became a pest on Brazilian soybean; among these new pests was a member of the Alydinae (see Panizzi & Slansky 1986, Panizzi 1988, 1989, 1997a, b; Panizzi & Corrêa-Ferreira 1997).

Systematics and phylogeny would have allowed us to predict that this alydine might become a pest on soybean—because 1) it belongs to a group all of whose members feed on legumes (Alydinae), and 2) it occurs wild in the very regions where soybean is now grown. What more can systematics tell us about this bug?

This soybean pest has been included in the genus *Megalotomus*, as *M. parvus* (Westwood). We know quite a bit about the biology of another species of *Megalotomus*, *M. quinquespinosus* (Say) (Yonke & Medler 1965). Presumably then we can use this information about one species of *Megalotomus* to help control the soybean pest. However, systematics tells us that we cannot. In his unpublished 1964 dissertation, J. C. Schaffner showed that the Neotropical species included in *Megalotomus* are in fact unrelated to the rest of the species in this genus. In particular, *M. parvus* is not related to *M. quinquespinosus*. Therefore any attempt to extrapolate knowledge about *M. quinquespinosus* to *M. parvus* would be wrong; and any attempt to control *M. parvus* using what we know about *M. quinquespinosus*, would waste time and money. But because Schaffner's dissertation has remained unpublished, this soybean pest has remained in the wrong genus. The sort of predictions I mentioned at the beginning of this talk can in this case not be made; and, if they had been, they might have been wrong. And the reason they cannot be made, or would have been wrong, is a systematic one: These two species of alydines are not related except at the subfamily level. Therefore we could have predicted that both would feed on legumes. But we could not have predicted that what we know about the biology of *M. quinquespinosus* might be true also of *M. parvus,* except insofar as both belong to the same subfamily (Alydinae). They do not belong to the same genus. Thus, because they belong to the same subfamily, we can make some predictions; but if they belonged to the same genus, we could have made even more—but we cannot.

The systematic confusion here has now been cleared up, with the publishing of the new generic name for *parvus: Neomegalotomus* (Schaffner & Schaefer 1998). And more information on the biology of *Neomegalotomus parvus* (Westwood) is now available (Santos & Panizzi 1998). The genus itself (*Neomegalotomus*) is being revised (Schaefer, in preparation). A more accurate knowledge of its systematics, and the more thorough knowledge of its biology provided by Panizzi and his colleagues, will together make easier the control of this soybean pest.

My third example is more serious than the other two, because it involves human health. It too concerns Brazil, although not directly. The subfamily Triatominae of the heteropteran family Reduviidae contains the vectors of Chagas' disease. Brazilians better than anyone know about Chagas' disease, not only because it is a serious disease in Brazil, but because so much of the work on the disease, especially on the biological and ecological aspects of the disease and its vectors, has been carried out at the Oswaldo Cruz Institute (in a building designed by Oswaldo Cruz himself). Indeed, the disease was discovered here by Carlos Chagas, and his classic paper was published in the first volume of the Institute's *Memórias* (see Morel 1998). Much, if not most, of the major work since, especially on the systematics of the trypanosome and its vectors, has continued to be published in these *Memórias*.

The Triatominae contains 16 genera and about 120 species (Lent &Wygodzinsky 1979, Maldonado C. 1990, Carcavallo *et al*. 1997, Jurberg & Galvão 1997). All of these except a few species of the genus *Triatoma*, and members of the genus *Linshcosteus*, live in the New World tropics or semitropics, from southwestern United States south into Chile and Argentina. Most New World members of the subfamily can transmit the trypanosome which causes Chagas' disease (although because of their biologies or behaviors, many of these species do not threaten humans).

Several members of *Triatoma* live in the Old World tropics; and the four or five species of *Linshcosteus* all live in India. So far, Chagas' disease has not been reported in these areas. However, trypanosomes close to *Trypanosoma cruzi* Chagas occur in these regions, and so of course do small mammals, especially rodents—the wild reservoirs of the trypanosomes and the wild hosts of the bugs.

Chagas' disease is a remarkably serious one (although remarkably little known in the United States). This trypanosomiasis severely harms the health of some 100,000 people a year from Mexico to southern South America, at an estimated treatment cost of some US$40 million annually (Schofield 1994, and see Schaefer 1995). Might this serious disease ever develop in India?

It has been suggested that *Linshcosteus* (the Indian triatomine) is not actually a triatomine, although phylogenetic evidence for this view is scant (Schofield 1988, J.-M. Bérenger [letter to me, 1997], Gorla *et al*. 1997) (this last was a morphometric study).

Thus several people who are very familiar with these bugs (Schofield) or are at least well acquainted with them, believe that *Linshcosteus* is phylogenetically more closely related to some other subfamily than to

Triatominae. *Linshcosteus* looks like a triatomine (so the suggestion goes) because it has independently come to feed upon vertebrate (and sometimes human) blood—just as have the lygaeids *Mizaldus* and the cleradines (see Schaefer 1997). Maria Coscarón of the La Plata Museum and I plan to study the phylogenetic relationships of *Linshcosteus*, looking not only at morphology but using also biological and behavioral data gathered by a student of Dunston Ambrose, of Palayankottai, India.

This study is of great practical interest. If *Linshocosteus* is truly a member of the Triatominae—that is, if *Linshcosteus* is phylogenetically closely related to the New World Chagas' vectors,—then it may also itself become a vector of *T. cruzi*, or of some Indian relative equally able to cause disease in humans. In other words, if a study of the bug's phylogeny reveals that its systematic placement is correct, *Linshcosteus* may become a disease vector in India.

On the other hand, if Schofield, Bérenger, and Gorla *et al*. are correct, then *Linshcosteus* is not related to the Chagas vectors, is not correctly placed systematically, and is not likely to be a vector of Chagas' disease or of some disease similar to Chagas'. I think it is clear that establishing the phylogenetic relationships, and thus the systematic placement, of *Linshcosteus* is of literally vital importance.

Next I shall discuss some insects that may become pests, especially of crops that are relatively new to an area.

In two recent papers, Antônio Panizzi, has discussed many of the practical and ecological aspects of my paper. In his Annual Review of Entomology article (1997a), he considers the importance of wild hosts to the lives of pest pentatomids. He points out that these pest pentatomids usually do not abandon or forsake their wild hosts, when these bugs move onto crops. Rather, the wild hosts serve as reservoirs, maintaining the pests when the crop plants are not available. Therefore it is important to know what these wild host plants are—and this is another practical taxonomic and systematic question, but of plants, not insects.

I would add that it is also important to know what the relatives of these pest pentatomids are, even relatives not now feeding on crops. If these relatives of the pests feed on wild relatives of the crops, then the relatives of the pests may themselves become pests.

Also in 1997, Panizzi (1997b) and Panizzi & Corrêa-Ferreira (1997) looked at the changes in the soybean fauna over the last quarter-century, when soybean has become a major crop in Brazil. They noted that some insects quickly became pests; that other insects gradually became pests; and that still other insects became important pests at first but gradually became less important. In many cases the differences were associated with parasites in the soybean fields. Therefore we need to know not only what these parasites are. We should also know what the relatives of these parasites are, for some of them may parasitize insects that feed on wild relatives of crops. And this is another practical taxonomic and systematic question, but of parasites, not pests. And so, wherever we look—crops, wild reservoirs, pests, parasites—we see the need for systematics. Systematics helps us predict what arthropods may become pests, what wild plants they live on, what crops they may attack, and what enemies they may have, parasites and predators. Certainly systematics is a practical study.

I might add that it may be the absence of parasites that allows an insect to become a pest rapidly. When a wild insect moves from its usual wild hostplant to a new crop, it gains several advantages. The obvious advantage is a food source that is both very abundant and very accessible. After all, if 1,000 hectares are planted to soybean, an insect feeding on soybean can find its food very easily. There is also another advantage. When the insect moves from a wild hostplant to a crop, that insect may leave behind predators and parasites associated with the old hostplants. Many parasites and predators find their hosts by first looking for the plants those hosts feed on. If those hosts are now feeding on a different plant, they can escape those parasites and predators—at least for a while. During that period of release (before parasites and predators find them), the new pests can build up large populations, especially of course because they now have an abundant supply of new food.

However, just as the introduction of a new crop affords prospective pests a new vast source of food, so do those pests themselves offer a large source of food to pests and parasites. Pests and parasites too will increase both in population and in number of species. Panizzi & Corrêa-Ferreira (1997) show this: from 1970 to 1997, the number of species (including nonHeteroptera) of soybean pests increased from about 10 to 25 (a 250% increase); the numbers of species of pests and parasites in soybean fields increased (1970-1997) from 20 to 95 (a greater increase, 450%). More specifically, the number of parasites of pentatomid eggs and adults increased from about 3 species to about 35—an increase of 1167% (calculated from Figs. 1 and 2, of Panizzi & Corrêa-Ferreira [1997]).

A knowledge of systematics and phylogeny allows one to make some predictions about future pests. For if one knows something about the biology of some members of a group, a knowledge of that group's systematics and phylogeny allows one, by extrapolation, to explore possibilities about other members of that group. In exactly the same way, we can predict that any new species of insect will have six legs—because if the new organism is an insect, our knowledge of arthropod phylogeny and systematics tells us that this new entity must have six legs. (I shall not discuss the possible circular reasoning here.)

Predictions about the possible pest status of a species may have two bases. If all or most members of the group feed on one or a few groups of plants, then any member of that insect group may become a pest on commercially grown members of that group of plants. Because other biological and ecological circumstances must be right, insects of this group do not inevitably become pests. But they may do so. The alydid *N. parvus* represents this situation, as I have already mentioned. When soybean was first planted in Brazil, it could have been predicted that some member of the subfamily Alydinae might become a soybean pest. Another example is the pentatomid genus *Piezodorus*. In Japan, *Piezodorus hybneri* (Gmelin) is a soybean pest (Higuchi 1997). It is not surprising then that, in Brazil, another member of the genus, *P. guildinii*, has also become a soybean pest (Panizzi & Slansky 1985).

The other basis for predicting pest status, is membership of a species in a group all or most of whose members feed very generally. Many, if not most, Pentatomidae are general feeders; it is not surprising then that many heteropteran pests belong to this family. A coreid, *L. zonatus*, also represents this situation. This coreid belongs to a tribe nearly all of whose members feed widely on plants in many families (Schaefer & Mitchell 1983, Mitchell 1980). In Brazil, *L. zonatus*, found usually on corn, is now found increasingly on soybean (Panizzi 1989).

I shall consider now three crops whose importance is increasing in Brazil: wheat, sugarcane, and rice. Each of these crops has important heteropteran pests in other parts of the world, but few heteropteran pests in Brazil. Will there ever be heteropteran pests of these crops in Brazil? Can a knowledge of the phylogenetic relationships of these pests help answer this question?

Henry (1997) analyzed the family Lygaeidae and its relatives. One result of the analysis was a decision that many of the subfamilies of Lygaeidae should in fact be families in a superfamily Lygaeoidea. Therefore, my first two examples are now in the family Blissidae, although formerly they were members of the lygaeid subfamily Blissinae. All blissids feed on monocotyledonous plants. The two examples are, first, pests of wheat, and, second, of sugarcane.

In North America, one of the most serious pests of wheat is the chinch bug, *Blissus leucopterus* (Say). This insect causes millions of dollars of damage a year. In Brazil or near

Brazil are several other species of *Blissus* (Slater 1964); and several other species collected in Brazil have never been described (Slater 1996, personal communication). These *Blissus* species now feed on wild grasses. Recently, *B. slateri* Leonard has been recorded in large numbers on valuable range grasses (Valério *et al*. 1998).

For the past 50 years or so, wheat has been grown in the states of Paraná and Rio Grande do Sul—about one and half million hectares per year (Panizzi 1998, personal communication). It seems possible that, sooner or later, one of these *Blissus* species will discover wheat, and move from wild grasses to this rich, new, and abundant source of food. Unfortunately, the systematics, and the biology and ecology, of South American *Blissus* are almost completely unknown. Clearly it is important to learn more about these South American insects.

In Brazil, sugarcane has been grown for about 50 years, in substantial amounts (4,753,000 ha/year), in São Paulo and other northeastern states (Panizzi 1998, personal communication).

Species in the lygaeid genus *Cavelerius* are sometimes serious pests of sugarcane in Asia (see references in Slater & Miyamoto 1963). *Cavelerius* also belongs to the large lygaeoid family Blissidae. This genus is closely related to *Ischnodemus* (Slater 1979), many of whose species occur in the New World (Slater & Wilcox 1969). The phylogeny of *Ischnodemus* is complex and poorly worked out (Slater 1979), but there are altogether 13 groups of species, and five of these groups occur in the New World. One of these is Nearctic and another does not feed on grasses. Members of the other three groups do feed on grasses (as far as is known). There are nearly 30 South American species in these three groups, and it is possible that one or more of them may become pests on sugarcane. This prediction is based of course on phylogeny—on the fact that this genus, *Ischnodemus*, is closely related to known sugarcane pests, members of *Cavelerius*—even though the latter genus is Asian. I should mention that although the South American *Ischnodemus* are fairly well known taxonomically (thanks to the work of J. A. Slater), their biology and their evolutionary relationships are virtually unknown. This of course is true also of most other South American lygaeoids. Because Brazilian *Ischnodemus* could become pests of monocot crops like sugarcane, I recommend that grassy areas near sugarcane fields be searched for *Ischnodemus*, and indeed for other blissids.

In Asia, very serious pests of rice (both dry-field rice and paddy rice) are members of the same heteropteran family, Alydidae, as the Brazilian soybean pests, *Neomegalotomus*. These rice pests however belong to a different subfamily, Micrelytrinae, many of whose members feed on grasses. These rice pests are species in the genera *Stenocoris* and *Leptocorisa*. The groups have been revised by Ahmad (1965), and in the New World there are species of both genera extending from the southern United States into Brazil. The New World species so far have not attacked rice (see Hussey 1951).

Rice has been grown in Brazil for about half a century, paddy rice in Rio Grande do Sul and dry rice in central Brazil (mostly Goiás State), for a total of about 3,565,000 hectares (Panizzi 1998, personal communication). With close relatives of these Asian rice pests in Brazil, the possibility exists that the Brazilian ones will also attack Brazilian rice. Once again, a knowledge of systematic and evolutionary relationships of the Brazilian *Leptocorisa* and *Stenocoris* provides a warning.

A species of *Leptocorisa* was recently found to infest soybean and rubber plant (Panizzi, unpublished). If these insects were indeed *Leptocorisa*, I predict they will not become serious pests. I base this on the fact that all of *Leptocorisa's* close relatives, and all known species of the genus itself, feed on monocots—mostly grasses. Again, knowing the systematics and the phylogenetic history of these bugs, it is safe to say they will not become serious pests of nongrasses like soybean and rubber.

These are just a few of many examples I could mention, of heteropterans which are pests outside of Brazil on crops also grown in Brazil. These pests have close relatives in Brazil, and the danger is always present, that these relatives of the pests will move from the relatives of the crop, to become pests on the crops themselves. As we know, this has already occurred with *N. parvus*, and with several species of Pentatomidae.

This potential problem may work in reverse. Sunflower is grown commercially in several states in Brazil. A minor pest of sunflower is the lygaeid *Xyonysius major* (Berg) (Schaefer 1998). A very close relative (see Schaefer 1998) of this species, *Xyonysius californicus* (Stål), occurs throughout the United States, including Kansas. Sunflower is grown commercially in Kansas, and although *X. californicus* is not a pest on sunflower there, one might predict that it could become a pest—because of the experience in Brazil, where the bug's relative is a pest (although not an important one) on sunflower.

These examples could be multiplied, and in many ways—the numbers of kinds of insects which are pests in one area and have nonpest relatives in other areas; the numbers of crops which have noncrop relatives in other areas and insects that feed on them. The possibilities are very great indeed.

Unfortunately, applied or practical entomology is very much a today study; the emphasis is very much on controlling the pests of today. Little time is spent studying future possibilities—that is, little time and little money and little energy are devoted to trying to predict what arthropods (insects and mites) might become pests in the future. Yet this is very important, because it gives entomologists the chance to be ready for these new pests—to study their biology and ecology, in order to prepare defenses against them, in order to be ready when (and if) these arthropods do indeed become pests.

This advance warning is especially important to a developing country, to a country developing its agriculture, and diversifying its agriculture by introducing new crops. Such a country is doubly vulnerable to new pests, because most developing countries are tropical or subtropical. Tropical countries, of course, have a much higher diversity of plant and animal species, many more kinds of organisms than do temperate countries (like the U.S.A.). This means that a crop new to a developing country may have native relatives already living in that country. If this is so, these different wild native plant relatives will have many different insects and mites feeding on them. And if *this* is so (and I believe it is), then there will be a large reservoir of native arthropods available, and from this reservoir there may emerge new pests on these new crops. There may also emerge populations of parasites and predators to help control these new pests. (Relatives of some of these parasites and predators may prove useful in controlling pests in temperate countries: The systematic research I advocate benefits everyone.)

It follows from this argument that we need to know much more about the arthropods of developing countries. The paradox is, of course, that *because* these countries *are* developing, and must develop, they lack resources; such resources as they have, must be used for the development itself, not for longer-range studies, or studies that may never yield practical results. In other words, developing countries often feel that long-range studies (such as studies of arthropods of no immediate economic importance) are a waste—that they are esoteric, like the study of Brahms, or of Dickens.

The further paradox is that the need for short-range control of pests usually means applying pesticides. But pesticides become ever more toxic and expensive (and therefore more dangerous to humans and the environment, and therefore less practical) every year, as resistance to them develops. More and more developing countries are trying to turn away from complete reliance on pesticides, and turning to some form of integrated pest management (IPM).

And here lies the final paradox: IPM requires a knowledge of the biology of the pest, and also of its parasites and predators. Yet if pesticides have wiped out these parasites and predators, and if a lack of taxonomic knowledge prevents one from knowing what they were, then it becomes impossible to study them and difficult to find them elsewhere and re-introduce them. This means that effective IPM is doomed, or at the least greatly delayed.

And so studies of the evolutionary relationships of noneconomic arthropods, and of their biology and ecology, are in fact neither a waste nor expensive. As I hope I have shown, these studies may prepare growers for new pests, these studies may help growers be ready to combat new pests. This ability is hardly a waste.... And basic studies of native arthropods are not expensive, or certainly not so expensive as physiological research, or medical research, or molecular research. People studying systematics and biology do not need much equipment, and that equipment is not expensive. What these people need is a little technical assistance, and reasonable salaries. These are not expensive.

There are other advantages of these studies—practical advantages. First, a country which encourages research on its biota gains considerable recognition from scientists and other intellectuals in the world—that is, from important people who shape public and official opinion. This is not a negligible advantage.

Second, a country which encourages research on its biota, and works to preserve that biota, gains both prestige in the world and increased tourism—I think of Guyana, and its decision to set aside a million acres as a natural preserve; I think of Costa Rica, which is developing ecotourism as an important source of income; and I think of Brazil, with its excellent, although sometimes faltering, attempts to preserve at least parts of the Amazon region, perhaps the most important biological resource in the world.

And third, it satisfies one to know about one's surroundings and about the natural world in which one lives. I cannot put a commercial value on this satisfaction, but it is a universal one and a very important one. As I have said, the need to know, to satisfy curiosity, is a deeply human need.

I may seem to have wandered far from my topic. I may have wandered, but not far. Let me return to my theme: The more we know about our world, the better prepared we are to live in it. Organisms in our world may appear not to affect us at all. But many do in fact affect us, and many others may affect us in the future. The more we know about them, the better prepared we are. We may learn about organisms by studying them, of course; but we may also learn about some organisms by studying their evolutionary relatives: That is to say, we may learn about some organisms by recognizing what their relatives are, and by applying to those organisms what we already know about their relatives. The examples I have given all come from the hemipteran suborder Heteroptera. As I have suggested, many more examples could be gathered from other, and larger, orders of insects and mites. Brazil contains many entomologists, whose work is known and respected throughout the world. I urge you to devote some of your efforts and your excellence to studying your own insects and mites—to studying those that may not seem to have economic value. From this information may come the bases for making predictions about what new economic value some of these arthropods may yield—as resources or as pests. Making predictions is what scientists do. Making predictions about the lives of living things is what systematicists do. And making such predictions about possible pests, is very practical entomology.

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