

## PROBLEMS AND NEEDS IN THE STUDY OF HOMOPTERA IN NORTH AMERICA

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### Abstract

The Order Homoptera is represented in North America by 3 suborders, 38 families with 1,044 genera, and 6,970 species. In addition, about 38% of the species are still undescribed, and about 90% of the immature stages need to be described for the first time. Several families have never been revised, while the number of specialists for most groups has decreased during the past 30 years.

Despite the apparent deficiencies in our knowledge for this order, a number of available species and genera catalogs, and also bibliographies, make its study easier, especially for newcomers. Because atmospheric pollution often causes an increase in homopteran populations, while a number of species are negatively affected by urbanization and habitat destruction in North America, it becomes more urgent than ever before to increase our research on homopterans.

### Introduction

This is the first status report on the taxonomy of the Homoptera in North America. An earlier synopsis (Kosztarab 1982) of world coverage dealt only with the higher classification of this order, while the genera in America, north of Mexico, were listed by Arnett (1985). Contributions to this manuscript were: text for the introduction and the section on Coccinea, Kosztarab; Cicadellidae, Freytag; Membracoidea, Deitz; the rest of Auchenorrhyncha, O'Brien; Sternorrhyncha, Stoetzel.

The order Homoptera is related to Hemiptera and sometimes, along with Heteroptera, is treated as a suborder of Hemiptera. It includes a diverse assemblage of taxa, and most homopteran workers specialize on one family or superfamily. Our work was made more difficult because there are no comprehensive treatments of the order, nor of the suborders treated here; therefore, we had to try to assemble the bits of information scattered in a wide range of publications. In addition, several of the families have not been revised or treated in detail.

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These difficulties are magnified because in North America so few homopteran workers are specifically employed, even on a part-time basis, to study certain families, and to provide species determinations. These individuals are employed by the federal governments of Canada and the United States, and by the state governments of California, Florida, and Illinois. Because of the economic importance of many Homoptera as pests of cultivated and ornamental plants and as vectors of plant viruses and other disease pathogens, the study of some species (e.g., San Jose scale) was mandated as early as the 19th century by legislation of both federal and state governments. Despite the early and increasing attention given to this group, the number of positions dealing with homopteran research has decreased in North America in recent years. For example, between 1953 and 1983 it decreased from four to one and a half positions in the U.S. Department of Agriculture. Thus, most of the current Homoptera research in the United States is being done on a part-time basis by university professors. The situation is not much better than in 1957 when Ferris described the acute shortage of professional workers in the field (Ferris 1957). Nonetheless, we are fortunate to have a number of active colleagues in mid-career at universities today who, inspired by their graduate studies on homopteran taxa, have continued research on certain families. These workers are training some badly needed replacements. But where are the jobs for new taxonomists? An increasing number of university departments are phasing out taxonomic positions. By not filling these positions, we are creating many "orphaned collections," and neglecting and mismanaging them. We are lucky if these collections, without caretakers, are offered to another institution where appropriate curation is assured. Those in charge of filling vacancies should be aware of what may result from action or inaction. Without adequate taxonomic experts, North America may face a situation and consequences similar to one in Hungary when the San Jose scale accidentally entered that country in 1927. Because the country had no scale insect specialists, newly discovered scale insects were sent to the other end of the continent (Hamburg) for species verification. By the time an identification was made, the San Jose scale had spread too far to be eradicated. This pest currently causes the loss of tens of millions of dollars in Europe each year.

Immature stages of the Homoptera are very poorly known in general (Table 1). However, a key to families is being published (O'Brien et al. 1990).

The order Homoptera is divided into four suborders: Coleorrhyncha, Auchenorrhyncha, Sternorrhyncha, and Coccinea. Because Coleorrhyncha occur only in the Southern Hemisphere, they are not treated in this paper. The suborder name Coccinea was introduced by Beier (1938), and accepted by a number of European workers, including the first author.

**Table 1. Summary of Homoptera descriptions in North America.**

Suborders	Number of				
	Described Taxa			Undescribed	
	Family	Genus	Species	Species	% Nymphs
Auchenorrhyncha	16	514	4199	1392	90-99
Sternorrhyncha	5	335	1915	3380	90-95
Coccinea	17	195	856	324	50-100
<b>Total</b>	<b>38</b>	<b>1044</b>	<b>6970</b>	<b>5096</b>	<b>Ave. 90%</b>

Total species described and undescribed = 12,066

Percent of species still undescribed = 38 %

Estimated total no. of undescribed nymphal forms = 25,092

(Calculated by taking 90% (6,273) of the total described species (6,970) and multiplying it by 4, the average number of immature or nymphal stages in each species).

SUBORDER AUCHENORRHYNCHA--CICADAS, TREEHOPPERS,  
SPITTLEBUGS, LEAFHOPPERS, AND PLANTHOPPERS  
(or, as a group, jumping Homoptera, and cicadas).

The taxonomy of the species in this suborder is often based primarily on male genitalic characters. The different families are known at different levels of sophistication. Some families (e. g., Delphacidae) lack even keys to genera or subfamilies, so that one must read hundreds of original descriptions to identify species. In the case of nymphs, 90 to 99% are undescribed, but a key to fifth instars of the families will soon be available (O'Brien et al. 1990). Knowledge of the species in most taxa south of the United States is limited, so meaningful phylogenetic studies are lacking at the generic level and above. Many species remain to be described, but emphasis has been placed on descriptions for the United States and Canadian species, although the greatest number of endangered species are found in tropical forests that are being destroyed. The number of Homoptera specialists has decreased in the last thirty years because biologists from other disciplines have replaced systematic entomologists in academic work throughout the universities. Table 2 gives the current number of workers.

Z. P. Metcalf's bibliographies and catalogs (Metcalf 1932-1947, 1944, 1954-1966, 1960-1963, 1962-1964, 1962-1971; Metcalf and Wade 1963-1965) are the greatest assets to workers on Auchenorrhyncha, as they list for each species every paper discussing that insect, and categorize the information in each paper. The Auchenorrhyncha newsletter, "Tymbal," is published twice yearly by M. Wilson, CAB International Institute of Entomology, 56 Queen's Gate, London, SW7-5JR. The International Auchenorrhyncha Congress meets every three years in Europe, and an International Workshop on Leafhoppers and Planthoppers of Economic Importance has met periodically in the United States.

Among the major museums in the United States, the collections of the U.S. National Museum of Natural History and the California Academy of Sciences are especially outstanding. North Carolina State University has the important collection of Metcalf and the reprint collection used to compile his catalogues; the University of Kansas has the collections studied by R. H. Beamer and K. C. Doering and their students; and The Ohio State University has the H. Osborn and D. M. DeLong collections. More collections are given in the discussions of the taxa. Recent workers were listed by Wilson (1981).

**Superfamily Cicadoidea--Cicadas**

**Family Cicadidae**

There are 16 genera with approximately 180 species in North America. Of these, 4 genera and 14 species are represented in Canada, leaving possibly 2 more genera and 10 species to be anticipated. A catalog and bibliography are available for the North American species (Duffels and Van der Laan 1985). Other major recent works include those by Alexander and Moore (1962), Moore (1966), and Beirne (1961).

There are only 6 part-time researchers working on this family in North America at present. For several species we lack information on life cycle, host preferences, and the taxonomy of the immature stages. Studies are needed to pinpoint endangered habitats in North America, and to investigate the effects of acid rain and of the resulting low soil pH on the soil-inhabiting nymphs.

**Table 2. Assessment of Auchenorrhyncha in North America.**

Superfamily and family	Described number		Est. number undescribed species	Est. % of needed descriptions for nymphs	Date of species catalogue	Date of last manual	Number of specialists in N. Amer. ; % of time	Others
	gen.	spp.						
A. Cicadoidea Cicadidae	16	180	6%	prob. 99	1965	1962,1966	6 (part-time)	catalog 1965
B. Membracoidea Membracidae	60	265	10%	90	1965	partial 1973,1974	2; 30-50% each	bibl. 1963, 1987,1989
Aetalionidae	1	1	-	100	1960	-	-	-
C. Cercopoidea Cercopidae	9	65	-	25	1960,1961	Doering 1928 Hamilton 1962	1	bibl. 1960
D. Cicadelloidea Cicadellidae	260	2800	20%	90	1962-1971	1949-1956	1; 100% Can. 3;10-25% ea. U.S.	bibl. update in press
E. Fulgoroidea Delphacidae	49	303	10%	99	1943	1965	2; 10% ea.	* no keys
Derbidae	14	67	5%	99	1945	partial 1983-1986	-	*
Cixiidae	13	173	1%	99	1936	1977-1983	-	
Kinnaridae	1	6	-	99	1945	Kramer 1988	-	*
Dictyopharidae	15	77	5%	99	1946	partial 1943-1955	-	*
Fulgoridae	8	17	5%	99	1947	planned O'Brien	-	*
Achilidae	8	55	1%	99	1947	partial 1950-1971	-	*
Tropiduchidae	2	2	-	99	1954	O'Brien planned	-	*
Flatidae	14	33	20%	99	1957	1946	-	*
Acaloniidae	1	18	1%	99	1954	1932	-	*
Issidae	23	137	5%	99	1958	1936-1941	-	update O'Brien 1988
Total	514	4199	1-30%	90-99%				

**Superfamily Membracoidea--Treehoppers**

Treehoppers exhibit much morphological and behavioral diversity. Metcalf and Wade (1963-1965) recognized four families in the superfamily: **Aetalionidae, Biturritiidae, Nicomiidae, and Membracidae**. The taxonomic limits of these families are disputed (Evans 1948, Hamilton 1971, Deitz 1975, 1985), but only Aetalionidae and Membracidae occur in America north of Mexico.

Deitz (1985) reviewed earlier classifications of the **Aetalionidae** and, like Evans (1948), placed only *Aetalion*, of the New World (subfamily Aetalioninae), and *Darthula*, of the Oriental

Region (subfamily Darthulinae), in the family. The Neotropical genus *Aetalion* needs revision; one species, *Aetalion nervosopunctatum* Signoret, occurs in Arizona (Arnett 1985).

Deitz (1975) described 14 tribes (in 6 subfamilies) for the **Membracidae** of America north of Mexico. Caldwell (1949) and, recently, Kopp and Yonke (1979) have revised the large tribe Ceresini. Another large tribe in need of revision, Smiliini, is currently being examined by T. K. Wood; one part of this group (tribe Telamonini, now considered a synonym of Smiliini) was previously revised by Ball (1931). Taxa of the Centrodontini were revised by Cook (1952, 1953). The other tribes (Platycentrini, Nessorhinini, Hoplophorionini, Membracini, Hypso-prorini, Darnini, Acutalini, Micrutalini, Amastrini, Polyglyptini, and Microcentrini) also need revision but have relatively few North American members and should be examined in the context of their Neotropical relatives. Approximately 60 genera and 265 species of treehoppers are described from America north of Mexico. Possibly 10 percent of the North American species remain to be described, but this estimate may be conservative in light of recent observations on immature stages, host plant associations, and biology (see especially works by Wood and Guttman listed by Deitz and Kopp 1987 and Deitz 1989).

Published illustrations of the last instars of about 10 percent of the U.S. membracid species are available, but very few have been described in detail. The only extensive key to the immatures is to the genera of Missouri (Quisenberry et al. 1978). The immatures have excellent taxonomic characters and much useful work could be done with them.

Funkhouser's (1927) catalog together with Metcalf and Wade's catalog (1965) and bibliography (1963) provide full bibliographic access to literature on all membracoid taxa through 1955; recent bibliographies are by Deitz and Kopp (1987) and Deitz (1989). Major keys are: Aetalionidae--species of *Aetalion* (Goding 1927); Membracidae--subfamilies and tribes (Deitz 1975), genera (Funkhouser 1951), genera and species (Kopp and Yonke 1973-1974, 1977, 1979, with emphasis on Missouri taxa, but widely useful), Canadian taxa (Beirne 1961).

Approximately 5 workers in the U.S. actively publish: two deal primarily with systematics; 3 work primarily on ecology or speciation. These numbers translate to about 2 full-time equivalents in the U.S. (1 on systematics, 1 on ecology), but much time is directed towards taxa not occurring in North America. Additional workers in the U.S. and abroad are studying species of economic importance (see bibliographies by Deitz and Kopp 1987 and Deitz 1989).

Treehoppers occasionally cause serious injury to their host plants through feeding, oviposition, or disease transmission. Because existing keys and descriptions are frequently inadequate for identification, both applied and basic research is impeded. We need not only studies of ecology and behavior, but research on evolutionary relationships in order to provide a sound classification with greater predictive value for agriculture.

Major collections: American Museum of Natural History (Goding), California Academy of Science (Van Duzee), New York State Museum at Albany (Fitch), North Carolina State University (Metcalf), Ohio State University (DeLong), United States National Museum of Natural History (Funkhouser, Goding) and the University of California at Berkeley.

### **Superfamily Cercopoidea--Spittlebugs or Froghoppers**

The superfamily includes 1 family, 3 subfamilies, 9 genera, and 65 species in North America (Table 1). Subdivisions of this taxon were recently treated for North America in a series of papers (Hamilton 1977a,b, 1978, 1979, 1982a) updating our knowledge since Doering's (1928, 1930) synopses and Metcalf's bibliography and species catalogs (1960-1963). Hamilton's

(1982b) identification manual for the **Cercopidae** of Canada is the only comprehensive treatment from this area and covers Canada and the northern half of the U.S.

Because immatures often live in grass thatches, about 25% of the immature stages still need to be described. Probably less than 20% of the world fauna is described. Almost all the groups badly need revisions because the taxonomically important genitalic characters are practically unknown in the vast majority of genera. There are a number of undescribed species even in North America, particularly in the southwestern United States.

An endangered species recognized by Hamilton in southern Ontario and Michigan is *Philaronia canadensis* (Walley) which has almost been exterminated because of destruction of its habitat by agricultural activities. According to Hamilton, there are at present no other specialists in the world for spittlebugs. Their economic importance is generally underestimated.

### **Superfamily Cicadelloidea--Leafhoppers**

#### **Family Cicadellidae**

The family in North America includes 21 subfamilies and about 280 genera with 2800 described species (Table 1). It is estimated that 70% are already described. About 90% of the immature stages are also undescribed, and approximately 25% of the described species are known only from one sex. There are 3 United States specialists, each spending about 10 to 25% time on this taxon, and one full-time specialist in Canada. Unfortunately, 8 other North American workers recently retired. Worldwide, there are approximately 25 mostly part-time workers.

Many species have probably already been eliminated, but specific studies to clarify their status are lacking. Because many species are host-specific, when their host plant is endangered, the leafhopper is also endangered.

A number of graduate research projects are in progress, but opportunities for employment in systematics are few, and the outlook for financial assistance to support systematic research is bleak at present.

Major works available are those by Oman (1949) on generic classification, also Beirne (1956) on the fauna of Canada and Alaska, Young's (1968, 1977) works on the Cicadellinae, and Metcalf's (1962-1971) species catalog and bibliography. There is in progress an update on the bibliography by Knight et al. (1990) and a revision of Beirne's manual. Leafhoppers are of great economic importance and many are vectors of plant disease (Nault & Rodriguez 1985).

### **Superfamily Fulgoroidea--Planthoppers**

This superfamily includes 11 families in North America and 9 families in the rest of the world. Wilson and O'Brien are preparing a checklist of U. S. and Canadian species. There are several old keys for states (Mississippi, Ohio, Illinois), but if no modern revision is listed, one might try Metcalf's (1923); however, the names are not current. No other major works are in progress for this part of the world. The fulgoroid families have been cataloged by Metcalf (1932-1947; 1954-1966). Although about 2% of the world's species are economically important (Wilson & O'Brien 1987), most of the U. S. species have been controllable except for *Myndus crudus* Van Duzee, the vector of lethal yellowing of palms. Nymphs are slowly being associated with adults and described. An introduction to the superfamily was provided by O'Brien and Wilson (1985).

There are 303 species and 49 genera of **Delphacidae** in North America, but no key to genera and very few keys to species. To identify them one must compare the male genitalia to descriptions in the literature. Females often cannot be identified to species level. *Delphacodes*, with 102 North America species, is a Holarctic genus which Europeans have divided into many genera. New World species have not been examined and similarly placed. This family, with many virus vectors, should have priority for revision as it is economically the most important family of Fulgoroidea.

There are 67 species in 14 genera of **Derbidae** in North America. Flynn and Kramer (1983) and Kramer (1986) revised the genus *Cedusa* for the New World. The other 13 genera are not treated as a unit anywhere.

There are 173 species in 13 genera, with at least 1 new genus of **Cixiidae** in North America. The family was treated by Kramer (1977, 1979, 1981a,b, 1983), Mead and Kramer (1982), and O'Brien (1982).

A revision of the 6 known species in the genus *Oecliidius*, the only genus in the family **Kinnaridae** in North America, was begun by J. P. Kramer and awaits completion, probably by others.

There are 77 species in 15 genera in the family **Dictyopharidae** in North America. Doering and Darby (1943) and Doering (1955) prepared keys to the genera of Orgerinae and revised 3 genera. Breakey (1928) revised the genus *Scolops* with 23 species. Lawson and Beamer (1930) and Ball (1937) described an additional 5 species without illustrating male genitalia or placing the species into Breakey's key or using Breakey's characters. The other 10 species are described in widely scattered papers.

There are 17 species in 8 genera in **Fulgoridae** of this area. Kramer (1978) revised *Cyrpoptus*. O'Brien is working on a revision of the New World species.

There are 55 species in 8 genera of **Achilidae**. O'Brien (1971) revised the Plectoderini. Beirne (1950) revised the Canadian *Epiptera*, but a few additional species occur in the United States. One new cave-dwelling species has been discovered (Howarth, personal communication).

Three species in 3 genera of **Tropiduchidae** have been reported from the United States but 2 of these species are erroneous records. However, in a forthcoming note, O'Brien will report on 2 species in 2 genera.

Fennah (1984) placed 9 issid genera found in California in the **Nogodinidae**. Because he did not provide a character set to separate the 2 families, they cannot be separated by a simple key but must be identified to tribe through a series of four papers, including a key to 5 tribes, a description of 1 subfamily, and descriptions of 6 other tribes (Fennah 1954, 1978, 1984, 1987). For this reason, the old classification is followed here, in which no Nogodinidae are found in the United States and Canada.

Thirty-three species and 14 genera of **Flatidae** are found in North America. Doering and Shepherd (1946) revised *Mistharnophantia*. The other descriptions are scattered. A revision is badly needed.

There are 1 genus and 18 species of **Acanaloniidae** in this geographic area. Fennah (1954) reduced Acanaloniidae to a subfamily within the Issidae. Most Americans have not followed

him. Doering (1932) did an excellent monograph, but 3 species without illustrations have been described since.

Twenty-three genera and 137 species of *Issidae* are found in the United States and Canada, unless one follows Fennah (see *Nogodinidae*). Doering (1936-1941) published a model monograph of these species. O'Brien (1988) reported additions and synonymies and revised the key. New species are expected from the canyons of Southern California where much local endemism seems to occur. *Caliscelinae* were segregated into a separate family by Scudder (1979).

#### SUBORDER STERNORRHYNCHA--APHIDS, ADELGIDS, PHYLLOXERIDS, WHITEFLIES, AND PSYLLIDS

The suborder includes 5 families here, but some workers divide the *Aphididae* into several families. Table 3 provides a summary of the suborder.

**Table 3. Assessment of Sternorrhyncha in North America.**

Family	Described number		Undescribed (estimate)		Date of last manual	Number of specialists in N. America; % of time
	genus	species	% nymphs	# species		
<i>Aphididae</i>	280	1400	99	2800	1952 only regionals	3; @ 50%
<i>Adelgidae</i>	2	40	99	20	1928	2; @ 10%
<i>Phylloxeridae</i>	3-5	60	99	30	1904	1; @ 20%
<i>Aleyrodidae</i>	28	115 pupae	10 pupae	230	1947-1982	3; @ 10%
<i>Psyllidae</i>	40	300	90	300	1914-1943	1; @ 5%
<b>Total</b>	<b>335</b>	<b>1915</b>		<b>3380</b>		

#### **Family *Aphididae*--Aphids**

In North America there are approximately 1,400 species of aphids in 280 genera, and about twice that many remain to be described. The taxonomy of the group is based mainly on the alate (winged) and apterous (wingless) viviparous females. Only a few fundatrices (stem mothers), sexuales, or immatures have been described.

In North America, the *Aphidini*, *Myzini*, and *Macrosiphini* are in need of revision, and the whole family is poorly collected in many areas. Some references on aphids are Palmer 1952, Smith 1972, Dixon 1973 and 1985, Blackman 1974, Eastop and Hille Ris Lambers 1976, and Smith and Parron 1978.



An "Aphidologists Newsletter," published biannually in March and October, is available from RAHADL Consultants Ltd., P.O.Box 16-286, Christchurch, New Zealand.

In North America there are currently only three positions devoted at least 50% to aphid systematics. Another 5-6 researchers identify aphids in addition to other insect groups. One researcher works on aphid systematics in his spare time, and four retired aphidologists are still working on aphids. Several other individuals work with aphids as vectors of plant viruses. About 20 researchers throughout the world spend at least 30% of their time on the systematics of aphids.

There are several large collections of aphids in North America. The aphid portion of the collections in the U.S. National Museum of Natural History (USNM) of the Smithsonian Institution, Washington, D.C., is under the care of a research entomologist in the U.S. Department of Agriculture and is located at Beltsville, Maryland. The collection contains more than 70,000 slides representing approximately 2,005 primary and secondary types and 2,368 species. Early workers whose material is in the collection are A. Fitch, C. V. Riley, and T. Pergande. The L. G. Strom, F. C. Hottes, and a portion of A. G. Robinson Collections are components of the USNM. The collection is particularly strong in species encountered at ports of entry in the United States. The Canadian National Collection (CNC), Ottawa, consists of 110,000 slides with holotypes of 170 species and paratypes of 338 species. The CNC aphid collection is strong in Nearctic material with emphasis on Canadian, also arctic and subarctic species, and it has several ecological samples and long series of many species. In the Florida State Collection of Arthropods (FSCA) approximately 717 species of aphids, mostly North American, are represented on 31,553 slides, including 1,561 secondary type slides. The Illinois Natural History Collection (INHC) contains aphids representing 671 species in 173 genera. There are 49 holotypes, 8 neotypes, 19 lectotypes, and 47 syntypes in the INHC. The Robert C. Dickson aphid collection at the University of California, Riverside (UCR) contains approximately 1,450 species. The E. O. Essig aphid collection is housed at the University of California, Berkeley. The California Department of Food and Agriculture (CDFA) collection houses 7,763 slides. The North Carolina State University Insect Collection (NCSU) has nearly 50,000 slides, including 523 North American species in 155 genera, donated by C. F. Smith and A. T. Olive.

#### **Family Adelgidae--Adelgids**

In North America there are approximately 40 species of adelgids described in 2 genera, and about half that many species remain to be described. The taxonomy of the group is difficult because there are many developmental forms and many species move from the primary host *Picea*, (spruce), to a secondary host which is another conifer. Immatures of only a few species have been described, although the first instars have been shown to have taxonomic characters very reliable in separating species. The last comprehensive work on the family was by Annand (1928), and the whole family is in need of revision.

In North America all taxonomic work is performed by two researchers who spend more than 10% of their time on this family. A few workers have published on specific pest species. In the world, there are no more than five researchers who are working even 10% of their time on the systematics of adelgids.

The adelgid portion of the Entomological Collection in the USNM of the Smithsonian Institution, Washington, D.C., is under the care of an entomologist in the U.S. Department of Agriculture and is located at Beltsville, Maryland. The collection contains more than 5,000 slides representing approximately 11 primary and secondary types and 50 species. The collection contains the material studied by P. N. Annand. The Adelgidae in the CNC, Ottawa,

consists of approximately 5,000 slides. In the FSCA approximately 15 species of adelgids are represented on 106 slides. There are more than 74 slides in the CDFA collection.

#### **Family Phylloxeridae--Phylloxerids, Phylloxerans**

In North America there are approximately 60 species of phylloxerans or phylloxerids described in 3-5 genera. About half that number of species probably are undescribed, but about 10 may be synonyms because Stoetzel (1985a) has shown that some species host alternate from *Carya* as the primary host to a secondary host in *Quercus* or *Castanea*. Stoetzel's 1981 and 1985b publications on the identity and biological development of the four species of phylloxerans on pecan in the U.S. give a good account of the unusual developmental stages in the sexuales.

In North America, the family is poorly collected and needs revision. Although several individuals around the world work on the grape phylloxera, only one researcher, in the United States, works on this family and is in the process of revising the family on a worldwide basis.

The phylloxerid portion of the Entomological Collections in the USNM is under the care of a research entomologist in the U.S. Department of Agriculture and is located at Beltsville, Maryland. The collection contains over 10,000 slides representing approximately 12 primary and secondary types and 58 species. The collection contains the material studied by T. Pergande in preparation of his 1904 monograph. The Phylloxeridae in the CNC, Ottawa, consists of approximately 100 slides with 1 paratype. In the FSCA approximately 15 species of phylloxerids are represented on 298 slides. The CDFA collection contains 189 slides.

#### **Family Aleyrodidae--Whiteflies, Aleyrodids**

In North America approximately 115 species of aleyrodids or whiteflies have been described in 28 genera, and about twice that many species remain to be described. The taxonomy of the group is based almost entirely on the 4th immature stage, which is called a pupa. A few workers have begun to look at the adults, but rearing adults from associated pupae still remains the best way to obtain specimens for study.

In North America the family is poorly collected, and several genera need description and revision. Some references on whiteflies are Russell 1947, 1948, and 1974; Mound and Halsey 1978; and Gill 1982.

In North America there are only two or three researchers working on the systematics of whiteflies. In the world, another 10 or 15 researchers are working on pest species in the Aleyrodidae.

The aleyrodid portion of the Entomological Collections of the USNM is under the care of a research entomologist in the U.S. Department of Agriculture and is located at Beltsville, Maryland. The collection contains over 18,000 slides and 6,400 envelopes of dry material representing approximately 389 primary and secondary types and 675 species. Early workers whose material is in the collection are A. L. Quaintance and A. C. Baker (Quaintance and Baker 1913-1915 and 1917). The collection contains the material studied by L. M. Russell in preparation of her several publications on the Aleyrodidae. The Aleyrodidae in the CNC consists of about 100 slides. In the FSCA approximately 169 species and 42 secondary types of aleyrodids are represented on 8,085 slides. There are 2,337 slides in the CDFA collection.

### Family Psyllidae--Psyllids

In North America there are approximately 300 species of psyllids described in 40 genera, and about that many more species remain to be described. Previously, the taxonomy of the group was based only on the adults (Crawford 1914, Tuthill 1943); but recent work, largely in Great Britain, has shown the importance of immatures (White & Hodkinson 1985).

In North America no one is working on the systematics of the Psyllidae. The family is poorly collected in many areas and needs taxonomic revision. A few researchers have published on pest species such as the pear psylla, which has become a serious pest in the pear-growing areas of North America, and the apple sucker, which has been expanding its distribution throughout the northeastern United States. In the world are about 10 researchers working on the systematics of psyllids.

The psyllid portion of the Entomological Collection in the USNM is under the care of a research entomologist in the U.S. Department of Agriculture and is located at Beltsville, Maryland. The collection contains more than 22,000 pinned specimens, 3,000 slides, and three drawers of psyllids *in situ* on hosts representing approximately 1,187 primary and secondary types and 500 species. Early workers whose material is in the collection are T. Pergande, E. A. Schwarz, D. L. Crawford, and J. S. Caldwell. The L. D. Tuthill collection was donated to the USNM. The Psyllidae in the CNC consists of approximately 20,000 specimens and 25 types. In the FSCA approximately 100 species and 18 secondary types of psyllids are represented on 280 pinned specimens and 400 slides. The CDFA collection has 691 slides, 715 pinned specimens, and 364 alcohol vials with psyllids.

### SUBORDER COCCINEA--SCALE INSECTS

Terms used in the past for the entire group: Scales, Coccids, Coccoidea, Coccoidea.

This taxon, being unique in many ways, has deserved for some time to be treated as a suborder. It was already treated as a suborder by Beier (1938). After a number of European workers treated it as such, it is introduced here, probably for the first time in North America, as a suborder. Keys to separate it from other homopteran suborders, and to distinguish superfamilies and a number of families of the Coccinea, are given in Kosztarab and Kozar (1988). Howell and Williams (1976) provided an illustrated key to the families in North America. Advances in scale insect research have been reviewed by Miller and Kosztarab (1979).

More specific information is given under each family, but a summary that applies to the suborder in North America is presented here. The taxonomy, with very few exceptions, is based on the external morphology of adult females. Adult males and immatures have been described only in a few species in most families. About one-third to one-half of the species are still undescribed in North America (Table 4), but about three-fourths of the species are undescribed in the tropics. Most descriptions were based on only a few adult female specimens, and distributional records are inadequate for most species. The 856 species known in North America belong to 195 genera and may be included into up to 17 families. Most of the adult males and immatures remain undescribed.

The number of specialists working on Coccinea has decreased through the past 30 years to about a dozen part-time workers, mainly due to lack of financial support for systematic studies and graduate research. Consequently there are large gaps in our knowledge on this interesting group. To recruit new workers, Kosztarab (1987) recently summarized the uniqueness of scale insects.

**Table 4. Assessment of Coccinea in North America.**

Superfamily and family Amer.	Described number		Est. number undescribed species	Est. % of needed descriptions		Date of species catalogue	Date of last manual	Number of specialists in N.  % of time
	gen.	spp.		adults	nymphs			
<b>A. Orthezioidea</b>								
Ortheziidae	4	31	6	100	100	1903	1925 & 1952	none
Margarodidae	11	42	20	90	80	1903	1928	none
<b>B. Coccoidea</b>								
Putoidae	1	20	10	95	95	-	-	none
Pseudococcidae	45	230	120	95	95	1903	1950, 1953	1; 20%
Coccidae	23	93	46	90	90	1903	only regionals	4; @ 5%
Acleridae	1	16	5	95	95	1903	1953	none
Dactylopiidae	1	4	2	100	100	1903	1955	none
Kermesidae	4	33	3	100	60	-	1985	1; 5%
Cryptococcidae	1	2	2	-	80	-	-	1; 2%
Eriococcidae	10	52	40	95	95	1963	-	1; 5%
Kerridae	1	7	-	95	95	1958	1923	none
Lecanodiaspididae	1	5	5	60	50	-	1970, 1972, 1974	1; 2%
Cerococcidae	1	5	3	40	95	-	1977 & 1979	1; 2%
Asterolecaniidae	4	29	12	95	60	-	-	1; 5%
Conchaspidae	1	1	-	100	50	1981	-	none
Phoenicococcidae	1	1	-	-	-	-	1934	none
Diaspididae	85	285	50	95	95	1966(world) 1982 (US)	1937-1949	5; @ 5%
<b>Total</b>	<b>195</b>	<b>856</b>	<b>324</b>	<b>40-100%</b>	<b>50-100%</b>			

The first author found evidence both in the eastern U.S. and in Europe that, when extra nitrates were added through the tree foliage from atmospheric pollution, the size of the local scale insect population often increased, thus assisting with the destruction of trees already weakened physiologically. In certain species small localized scale insect populations are in endangered habitats, and some already have disappeared due to urbanization (e.g., *Conchaspis angraeci* Cockerell in some parts of Florida, and an undescribed *Toumeyella* species in southern Florida; also several *Kermes* species in the suburbs of Los Angeles and San Jose in California).

Major works in progress include a monograph on the economically important Diaspididae by D. R. Miller and J. A. Davidson; a series of identification manuals for the California species by R. J. Gill; a monograph on legless mealybugs by H. J. Hendricks and M. Kosztarab; and a revision of Dactylopiidae by G. Perez-Guerra and M. Kosztarab. Also in progress are generic revisions of Coccidae by M. L. Williams and coworkers; of Asterolecaniidae by P. L. Lambdin and coworkers; and a revision of Eriococcidae in the Eastern U.S. by D. R. Miller. A revision of *Chionaspis* was recently completed (Liu et al. 1989).

Because the Coccinea are extremely small, and their study requires mounting on microscope slides (a time-consuming process), many scientists are deterred from pursuing research on the group. However, the literature is well cataloged, including four issues each of annotated bibliographies and generic catalogs and the yearly publication since 1973 of the "Coccidologists' Newsletter," now called "The Scale," by D. R. Miller. The latter, in addition to providing yearly literature updating, has included a series of inventories of the major Coccinea collections in North America. A series of Coccidology Training Sessions (the 5th was in 1987) are given to introduce interested researchers to the taxonomy and biology of this unique group. Sessions

are offered every 2 or 3 years in June at the University of Maryland by organizer John A. Davidson.

The major Coccinea collections in the United States with active workers (at least on a part-time basis) are those at the USNM (housed in Beltsville, Maryland\*), the Ferris-McKenzie Collection at the University of California at Davis\*, the California Department of Food and Agriculture in Sacramento\*, the FSCA in Gainesville, the Virginia Polytechnic Institute and State University Collection in Blacksburg\*, the University of Georgia Experiment Station in Experiment, the Auburn University\*, the University of Tennessee in Knoxville, and the California Academy of Sciences in San Francisco. In Canada, the CNC in Ottawa\* has a sizable collection. Inventories for collections marked with an asterisk (\*) are available in the earlier issues of "Coccidologists' Newsletter" and "Scale."

There were two symposia series initiated by the first author dealing with the taxon: one in North America and another, international series held at different locations. The first is normally held during the national meeting of the Entomological Society of America. This was started in Portland, Oregon, in 1966 and continues to date. The next meeting will be in New Orleans December 2, 1990. The International Symposium of Scale Insect Studies (ISSIS) was initiated informally in Canberra, Australia, during the 14th (1972) International Congress of Entomology, and has continued through four formal meetings, with the 6th to be held in Krakow, Poland, in 1990.

**Superfamily Orthezioidea--Primitive Scale Insects.** Synonyms: Paleococcoidea and Archaeococcoidea, both without nomenclatural status.

The superfamily includes 2 families, Ortheziidae and Margarodidae in North America. The two other families assigned to the superfamily, Phenacoleachiidae and Carayonemidae, are distributed only in the New Zealand subregion and in South America, respectively.

#### **Family Ortheziidae--Ensign Scale Insects**

There are 31 species in 4 genera in North America. Although the family was well monographed for the first time by Morrison (1925, 1952), not all the adult females were described. Therefore, many females, as well as the available adult males and the immature stages, await a first description and illustration. At least 6 additional species remain to be described.

#### **Family Margarodidae--Giant Scale Insects**

Approximately 42 species in 11 genera occur in North America, with at least one-third of the species undescribed. The family, last treated by Morrison and Morrison (1923), also Morrison (1928), badly needs revision. Although Morrison made a notable effort to describe and illustrate, at least in part, all available stages of both sexes, due to the lack of material, and especially lack of larger series of specimens, his work needs to be updated. Before this update is done, a concerted effort should be made to collect more specimens and borrow the material scattered in collections worldwide.

**Superfamily Coccoidea--Advanced Scale Insects.** Synonyms: Neococcoidea and Neococco-morpha, both without nomenclatural status.

In North America there are 15 families assigned to this superfamily. Some workers lump the 15 into 11 families. This author and his coworkers have studied intensively the species and their developmental stages in the families of Cerococcidae, Cryptococcidae, Kermesidae, and Lecanodiaspididae, and found enough justification to treat them as distinct families.

#### **Family Putoidae--Giant Mealybugs**

The family includes 20 known species in 1 genus in North America and probably one-third of the species are still undescribed. Only in *Puto sandini* Washburn were the adult male and the biology studied, and almost all the immatures are still undescribed; therefore a family revision would be in order. Unfortunately, there is no North American specialist for the group.

#### **Family Pseudococcidae--Mealybugs**

There are approximately 230 species in 45 genera in North America; about 120 species remain to be described. It is the second largest family of Coccinea. The classification is based on adult females. Only in a few economically important species have immatures and adult males been described, e.g., *Phenacoccus dearnessi* (Miller & Appleby 1971). Although Ferris (1950, 1953) devoted two volumes of his Atlases to this group, and McKenzie (1967) monographed the California species, the family needs a thorough revision. Miller and McKenzie (1971, 1973) redescribed a number of poorly known species and added a new genus and 11 new species to the Nearctic fauna. There are thousands of undetermined slide-mounted specimens in the major collections marked as "*Pseudococcus* sp.," or "Pseudococcidae undet." Because of their economic importance in agriculture, the U.S. Department of Agriculture should re-establish taxonomic positions to deal with such groups.

#### **Family Coccidae--Soft Scale Insects**

Approximately 93 species in 23 genera occur in North America; thus Coccidae is the third largest family of scale insects. It is estimated that at least one-third more species remain to be described. The classification is based on the adult females. Although subspeciation is suspected in the *Parthenolecanium corni* - complex, this has not been studied. Adult males and immature stages have been described in only a few species. The taxonomic value of male tests was recognized by European workers, but North American scientists have not described or utilized them until recently. M. L. Williams and his graduate student, G. L. Miller, have just completed such a study.

Progress has been made with revisions of some genera, such as *Ceroplastes* (Gimpel et al. 1974), *Coccus* (Gill et al. 1977), with the description of immature stages of a few species (Ray and Williams 1980, 1982, 1983), and with regional identification manuals such as, for Virginia (Williams & Kosztarab 1972), for Florida (Hamon & Williams 1984), and also for California (Gill 1988).

The "Lecanium group" needs a revision urgently, as does the North American genus *Toumeyella*, which includes an undescribed species restricted to an endangered island habitat near the coast of Florida on *lignumvitae* trees. There is one research laboratory at Auburn University that provides training for specialists on this family at present.

#### **Family Aclerdidae--Flat Grass Scales**

Approximately 16 species in 1 genus occur in North America, with at least 5 remaining to be described. The classification is based on the morphology of adult females, although a number of first instars were described in the monograph by McConnell (1954). Adult males need to be described, and the entire family can use a more detailed study that would result in a more useable key, but there is no specialist for the group at present.

#### **Family Dactylopiidae--Cochineal Scale Insects**

Four species in 1 genus have been described from North America (Ferris 1955). The classification is based on adult females because the adult males and immatures were not described in the past. A world revision is in progress at the first author's institution by G. Perez-Guerra.

#### **Family Kermesidae--Gall-like Scale Insects**

Approximately 33 species in 4 genera are assigned to this family in North America, but 14 of the "*Kermes*" species are unplaced because of insufficient and unuseable specimens and the disappearance of type localities in the newly urbanized suburbs of some California cities. The family was just monographed for North America. The prereproductive or teneral females and third instars were described by Bullington and Kosztarab (1985), the first and second instars by Baer and Kosztarab (1985). The adult males are in need of an analysis. The recent classification is based on preadult or teneral females, but in some species the first instars provide useful and better morphological characters than their adults.

#### **Family Cryptococcidae--Bark Crevice Scales**

The family includes 2 species in 1 genus in North America (Kosztarab 1968), but more (at least 2) species can be expected when the bark crevices of forest trees are more closely checked. The classification is based on adult females, because males were never found, and there is a need to describe in detail more immature stages.

#### **Family Eriococcidae--Felt Scale Insects**

According to D.R. Miller (personal communication), there are approximately 54 described species in 11 genera in this family in North America (he included Cryptococcidae here), with at least 40 more species to be described. Ferris (1955) prepared descriptions and figured adult females of North American Eriococcidae, but his work needs updating. Miller and McKenzie (1967) revised *Ovaticoccus* and its relatives and provided a key to the North American genera of Eriococcidae. The U. S. Department of Agriculture and other federal agencies should fund doctoral or postdoctoral positions for monographing this and other families in North America. The classification is based on adult females, as very few adult males or immatures were described. Hoy (1963) cataloged the world species.

### **Family Kerridae (Lacciferidae, Tachardiidae)-- Lac Scale Insects**

Probably 7 described species in 1 genus occur in America north of Mexico with at least 3 more species known only from Mexico and 1 from Jamaica. Chamberlin (1923) monographed the world species based on morphological characteristics of adult females. A revision of that monograph is essential, with the inclusion of full illustrations for each species and descriptions of immature stages and of available adult males. Ferris (1955) did not include new information but illustrated one species in full. Kapur (1958) cataloged the 65 species of the world, and Varshney (1970) compiled a world bibliography for the family.

### **Family Lecanodiaspididae--False Pit Scales**

There are 5 species in 1 genus in this family. The family was recently revised: most of the first instars were described by Williams and Kosztarab (1970), adult females by Howell and Kosztarab (1972) and Lambdin and Kosztarab (1973), and adult males of 2 North American species by S.M.A. El-Samad Nada (1982). Nonetheless, all the second instars, most adult males and their developmental stages still need descriptions. The *Lecanodiaspis prosopidis* - complex requires a thorough revision that could result in a number of subspecies or host-induced morphs.

### **Family Cerococcidae--Ornate Pit Scales**

In North America there are 5 species in 1 genus, *Cerococcus*, with 3 more in Mexico. Probably up to 3 species are still to be described from the subtropical areas of the United States. The genus *Cerococcus* was recently revised, and from North America adult females of 5 species were described and illustrated by Lambdin and Kosztarab (1977), and 3 first instars by Hamon and Kosztarab (1979). Unfortunately, the rarely collected adult males, their development stages, and all second instar females still need to be described. There are only scant distribution records on most species, and the biology of only one species, *C. parrotti* (Hunter), has been studied (Howell et al. 1971).

### **Family Asterolecaniidae--Pit Scale Insects**

There are approximately 29 species in 4 genera in North America, with probably 12 species still undescribed. Russell (1941) revised the genus *Asterolecanium*. That work includes 26 North American species. She gave special attention to the adult females and first instars. This genus needs updating, and the genus *Mycetococcus* needs revision. In addition, we lack information on biology and distribution for most species. P. L. Lambdin is actively working on this group.

### **Family Conchaspidae--False Armored Scales**

This tropical family includes 1 genus with 1 species (*Conchaspis angraeci* Cockerell) from the United States. Only the adult female and first instar have been described. Its natural habitat on Key Largo, Florida, is threatened with urban development. The family was monographed by Mamet (1954) and recently cataloged for the world by Ben-Dov (1981). A new genus and species is known from southern Florida (D.M. Miller, personal communication).



### Family Phoenicococcidae--Palm Scale Insects

There is only 1 species in 1 genus. The red date scale, *Phoenicoccus marlatti* Cockerell, is associated with date cultivation in the southwestern United States; Stickney (1934) described fully all developmental stages.

### Family Diaspididae--Armored Scale Insects

Approximately 285 species in 85 genera occur in North America (Nakahara 1982). This is the largest family of Coccinea, and includes the species of most economic importance. Therefore, it has been more intensively studied than most others. Ferris (1937-1942) devoted his first four Atlases to the family. Several genera have been revised since 1942, but many are still badly in need of study. Regional manuals were completed for California (McKenzie 1956), Florida (Dekle 1976), and Ohio (Kosztarab 1963). Nakahara (1982) cataloged the species for the U. S. 48 conterminous states. About 50 more species remain to be described and, for most species in the family, all the adult males and immature stages. A research team at Experiment, Georgia, is making special efforts to provide needed descriptions and illustrations of immature stages for a number of species. Stoetzel and Davidson (1974) described the morphology and biology of 9 species. A monographic treatment of the more than 100 economically important species is in preparation by D. R. Miller and J. A. Davidson.

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