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Chapter 2.3 Predaceous Insects

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INTRODUCTION

Several species of insect prey upon tetranychid mites. They belong to Coleoptera, Thysanoptera, Hemiptera, Diptera, Neuroptera and Dermaptera. The degree of their adaptation to this prey as well as their efficiency in controlling mite populations varies with the species and the environmental conditions. This chapter will deal with the nomenclature and biology of insect predators; their utilization and their impact on spider mites will be discussed in Chapter 3.2.

Most papers published prior to 1970 have been reviewed by McMurtry et al. (1970) and their contents are quoted under this reference. In the following the name *Tetranychus urticae* Koch is used for mites of the complex *Tetranychus cinnabarinus* (Boisduval) — *T. urticae*, according to the synonymy published by Dupont (1979).

REARING AND HANDLING

The rearing of predaceous insects has been achieved on various scales. Although the methods were generally devised for one particular species they can often be adapted to other predators. The mass production of *Stethorus* species (Coleoptera) for field releases was described by Scriven and Fleschner (1960), who reared tetranychid prey on oranges, under controlled conditions. A sophisticated experimental device was developed by Lord (1971) for studying the predation of mirids (Heteroptera) reared on the host plant. Nevertheless, most biological experiments can be conducted in small plastic cages similar to those used, following many authors, by Gutierrez and Chazeau (1972); these are convenient for predaceous Coleoptera, Thysanoptera, Heteroptera, and for larvae of Diptera. A regular supply of healthy mites in sufficient numbers is necessary for successful rearing, and a glabrous vegetal support in the cage is recommended. Water barriers similar to those used for confining tetranychids and predaceous mites are hazardous for most insect predator immatures and are inadequate for winged adults.

STETHORUS (COLEOPTERA, COCCINELLIDAE)

The genus *Stethorus* Weise (*Nephopullus* Brěthes) may be classified in the monogeneric tribe Stethorini Dobzhansky (subfamily Scymninae), but many authors consider this homogeneous group to be part of the tribe Scymnini Costa.

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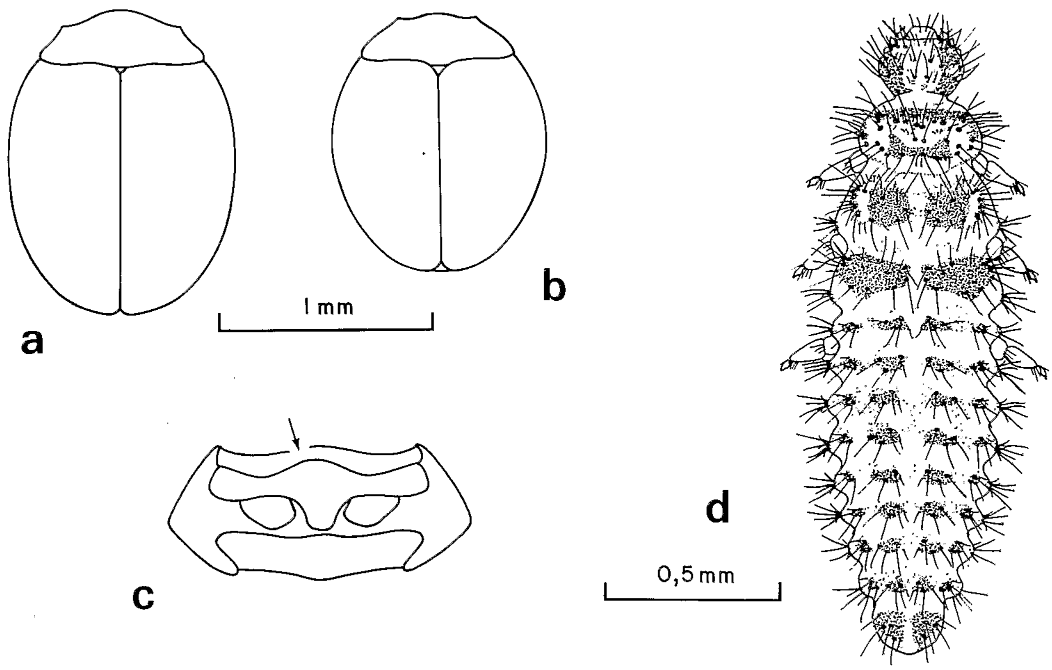

Fig. 2.3.1. *Stethorus* (a, b) Body outline of 2 *Stethorus* species, (a) *Stethorus picipes* Casey, (b) *Stethorus madecassus* Chazeau. (c) Schematic view of the prothorax; arrow indicates the protruding prosternum. (d) *Stethorus incompletus* Whitehead, larva (after Gordon and Anderson, 1979).

About 60 species have been described. These small (1—1.5 mm) pubescent coccinellids are easily separated from other Scymnini by the convex anterior margin of the prosternum. Almost all known species are black with brown or yellow appendices. They look very similar and identification of the females is difficult as they frequently lack sclerotized spermatheca. Dissection, slide mounting and microscopic observation of male genitalia is usually necessary in order to separate the species. Dissected parts are either stuck on bristol cardboard rectangles using water-soluble adhesive, or conserved in glycerin in small glass vials. Adult specimens are stuck on bristol cardboard; the soft larvae can be conserved in 70% proof ethanol. Adults and larva are illustrated in Fig. 2.3.1.

Stethorus beetles are present in areas of very different climates, from Canada to New Guinea, and in many ecosystems, including tropical rain forests, dry savannas, orchards and various crops.

Adults as well as larvae are highly specialized predators of tetranychid mites and to a lesser extent of tenuipalpids. Forty per cent of known species have been reported to attack spider mites of economic importance (Table 2.3.1). References to other diets are few: Kamiya (1966) listed several apids and diaspidids as prey for *Stethorus japonicus* Kamiya but he did not state the importance of these prey species. Kehat (1967) reported predation of adults of *Stethorus punctillum* Weise on the scale *Parlatoria blanchardi* Targ. Putman (1955) observed starving adults and larvae of *S. punctillum* feeding on aphids, but he concluded that this diet was inadequate for complete development and oviposition, though it increased adult survival. He also observed predation upon phytoseiids. Feeding on raisins and sweet foliar secretions causes extended adult longevity, as does drone powder (frozen or lyophilized larvae and young pupae of drone honey bees) in *S. japonicus* (K. Niijima, personal communication, 1980). Some results of biological studies on 3 species are summarized in Table 2.3.2.

Development includes 6 immature stages: the egg, 4 larval stages, and the

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TABLE 2.3.1

Some *Stethorus* predators of tetranychid mites on various crops

Predator and prey	Crop	Region	Ref.
Stethorus aethiops Wse			
Mononychellus tanajoa (Bondar) complex	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus urticae Koch	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus lombardinii B. & P.	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus neocaledonicus André	Cassava	Kenya	Yaseen et al. (1982)
Stethorus atomus Casey			
Eutetranychus banksi (McG.)	Citrus	Texas	McMurtry et al. (1970)
Oligonychus pratensis (Banks)	Sorghum	Texas	Ehler (1974)
Stethorus bifidus Kapur			
Panonychus ulmi (Koch)	Apple	New Zealand	McMurtry et al. (1970)
Bryobia sp. eggs	Apple	New Zealand	McMurtry et al. (1970)
Stethorus chengi Sasaji			
Tetranychus urticae Koch	Papaw	Taiwan	Wen and Lee (1981)
Stethorus comoriensis Chazeau			
Tetranychus neocaledonicus André	Breadfruit	Comoro I.	Chazeau (1971b)
Oligonychus coffeae (Nietner)	Plumeria	Comoro I.	Chazeau (1971b)
Stethorus darwini (Bréthes)[a]			
Tetranychus evansi (B. & P.)	Tomato	Brazil	Paschoal (1970)
Mononychellus caribbeanae McG., *Mononychellus tanajoa* (Bondar) complex, various tetranychids	Cassava	Guyana, Surinam	Yaseen et al. (1982)
Stethorus exspectatus Chazeau			
Tetranychus fijiensis Hirst	Coconut palm	New Guinea	Chazeau (1983)
Tetranychus lambi P. & B.	Cassava	New Guinea	Chazeau (1983)
Oligonychus, Panonychus, Schizotetranychus spp.	Various crops	New Guinea	Chazeau (1983)
Stethorus exsultabilis Chazeau			
Tetranychus fijiensis Hirst	Coconut palm	New Guinea	Chazeau (1983)
Tetranychus lambi P. & B.	Cassava	New Guinea	Chazeau (1983)
Oligonychus, Panonychus, Schizotetranychus spp.	Various crops	New Guinea	Chazeau (1983)
Stethorus fenestralis Houston			
Tetranychus lambi P. & B.	*Musa* sp.	Australia	Houston (1980)

TABLE 2.3.1. (Continued)

Predator and prey	Crop	Region	Ref.
Tetranychus lambi P. & B.	Papaw	Australia	Houston (1980)
Tetranychus urticae Koch	Papaw	Australia	Houston (1980)
Tetranychus kanzawai Kishida	Convolvulus	Australia	Houston (1980)
Stethorus fijiensis Kapur			
Oligonychus sp.	Coconut palm	Fiji	Chazeau (1979)
Tetranychus marianae McG.	Market crops, ornamentals	Fiji	Chazeau (1979)
Tetranychus lambi P. & B.	Market crops, ornamentals	Fiji	Chazeau (1979)
Stethorus fuerschi Chazeau			
Oligonychus chazeaui Gutierrez	Palm tree	Madagascar	Chazeau (1971b)
Tetranychus roseus Gutierrez	Palm tree	Madagascar	Chazeau (1971b)
Stethorus gilvifrons (Muls.)			
tetranychids	Various crops	Lebanon	McMurtry et al. (1970)
Tetranychus atlanticus McG.	—	Iraq	Georgis et al. (1976)
Stethorus griseus Whitehead			
tetranychids	Apple	New Zealand	Chazeau (1979)
Stethorus gutierrezi Chazeau			
Oligonychus sp.	Coconut palm	New Hebrides	Chazeau (1979)
Stethorus incompletus Whitehead[b]			
Tetranychus urticae Koch	Various vegetables	La Réunion	Chazeau et al. (1974)
Tetranychus urticae Koch	Papaw	Australia	Houston (1980)
Oligonychus sp.	Pine tree	Australia	Houston (1980)
Tetranychus kanzawai Kishida	Convolvulus	Australia	Houston (1980)
Tetranychus neocaledonicus André	—	New Caledonia	Chazeau (1979)
Oligonychus thelytokus Gutierrez	Litchi, Plumeria	New Caledonia	Chazeau (1979)
tetranychids	Apple	New Zealand	Chazeau (1979)
Stethorus japonicus Kamiya			
Panonychus citri (McG.)	Citrus	Japan	McMurtry et al. (1970)
Stethorus jejunus Casey			
Mononychellus tanajoa (Bondar) complex	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus urticae Koch	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus lombardinii B. & P.	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus neocaledonicus André	Cassava	Kenya	Yaseen et al. (1982)

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Stethorus loi Sasaji			
Tetranychus urticae Koch	Papaw	Taiwan	Wen and Lee (1981)
Stethorus loxtoni Britton & Lee			
Tetranychus lambi P. & B.	*Musa* sp.	Australia	Houston (1980)
Tetranychus urticae Koch	Soya	Australia	Houston (1980)
Stethorus madecassus Chazeau			
Tetranychus neocaledonicus André	Cotton	Madagascar	Chazeau (1971a)
Tetranychus spp., *Oligonychus* spp.	Various crops	Madagascar	Chazeau (1971a)
Stethorus pauperculus Wse.			
Oligonychus cucurbitae (Rah. & S.)	Papaw, castor, and various crops	India	Puttaswamy and Channabasavanna (1977)
Stethorus picipes Casey			
Oligonychus punicae (Hirst)	Avocado	California	McMurtry et al. (1969)
Panonychus citri (McG.)	Citrus	California	McMurtry et al. (1970)
tetranychids	Walnuts, melon, apple	U.S.A.	McMurtry et al. (1970)
Stethorus punctillum Wse.			
Eotetranychus carpini Oud.	Grapes	Italy	Laffi (1982)
Panonychus ulmi (Koch)	Fruit trees	Europe	McMurtry et al. (1970)
Panonychus ulmi (Koch)	Fruit trees	Canada	Putman (1955)
Tetranychus urticae Koch	Beans	Canada	Putman (1955)
Tetranychus urticae Koch	Greenhouse crops	The Netherlands	McMurtry et al. (1970)
Tetranychus urticae Koch	Beets	Israel	Plaut (1965)
tetranychids	Cotton, apple, watermelon	Israel	Plaut (1965)
tetranychids	Citrus	U.S.S.R.	McMurtry et al. (1970)
Stethorus punctum (Lec.)			
Panonychus ulmi (Koch) and various tetranychids	Fruit trees	North America	McMurtry et al. (1970)
Tetranychus mcdanieli McG.	Fruit trees	Canada	Robinson (1953)
Tetranychus pacificus McG.	Fruit trees	Canada	Robinson (1953)
Stethorus siphonulus Kapur			
Eutetranychus banksi McG.	Ornamentals	Hawaii	Raros and Haramoto (1974)
Oligonychus exsiccator (Zehntner)	Sugar cane	Hawaii	Raros and Haramoto (1974)
Tetranychus urticae Koch	Papaw	Hawaii	Raros and Haramoto (1974)
Tetranychus tumidus Banks	Papaw	Hawaii	Raros and Haramoto (1974)
Tetranychus neocaledonicus André	*Anona* sp.	French Polynesia	Chazeau (1979)

TABLE 2.3.1. (Continued)

Predator and prey	Crop	Region	Ref.
Stethorus tridens Gordon			
Tetranychus urticae Koch	Cassava	Columbia	Gordon (1982)
Stethorus utilis Horn			
Eotetranychus sexmaculatus (Riley)	Citrus	Florida	McMurtry et al. (1970)
Mononychellus caribbeanae McG., *Mononychellus tanajoa* (Bondar) complex, various tetranychids	Cassava	Columbia, Nicaragua, Trinidad	Yaseen et al. (1982)
Stethorus vagans Blkb.			
Oligonychus sp.	Pine tree	Australia	Houston (1980)
Tetranychus lambi P. & B.	Papaw	Australia	Houston (1980)
Tetranychus urticae Koch	Soya and beans	Australia	Houston (1980)
Bryobia praetiosa Koch	Fruit trees	Tasmania	Chazeau (1979)
Tetranychus marianae McG.	Ornamentals	New Hebrides	Chazeau (1979)
Oligonychus thelytokus Gutierrez	Litchi	New Caledonia	Chazeau (1979)
Oligonychus sp.	Coconut palm	New Caledonia	Chazeau (1979)
Tetranychus neocaledonicus André	Cassava	New Caledonia	Chazeau (1979)
Tetranychus lambi P. & B.	Cassava	New Caledonia	Chazeau (1979)
Tetranychus marianae McG.	Castor	New Caledonia	Chazeau (1979)
Tetranychus urticae Koch	Vegetables	New Caledonia	Chazeau (1979)

[a]Syn.: *S. ogloblini* Nunenmacher.
[b]Syn.: *S. histrio* Chazeau.

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TABLE 2.3.2

Some biological parameters observed for 3 species of *Stethorus* predators of tetranychid mites (mean in roman type; range in italics)

Predator: Prey:	*Stethorus punctillum* Wse. on *Tetranychus urticae* K.	*Stethorus picipes* Cas. on *Oligonychus punicae* (H.)	*Stethorus madecassus* Ch. on *Tetranychus neocaledonicus* A.
Temperature (°C)	21	24.5/*22—27*	25/*20—28.4*
Development time (days)	21.1/*20—23*	17.1/*15.8—19*	13.5/*11—21*
Length of preoviposition period (days)	*3—18*	5.6/*4—6*	4.2/*3—7*
Total progeny (eggs)	*197—1290*	221/*12—391*	184/*20—471*
Longevity of female (days)	*106—786*	90.0/*75—243*	43.6/*10—134*
$R_0/r_m/T$ [a]	—	103.26/0.121/38.3	92.38/0.155/29.2
No. of prey consumed during development	239 [b]	361/*325—379* [c]	491/*303—754* [d]
No. of prey consumed by ovipositing females (mite per day)	66.3/*52—87* [b]	35.9/*32—44* [e]	46.8/*11—80* [e]

From Putman (1955), Tanigoshi and McMurtry (1977) and Chazeau (1974a, b)
[a] R_0 = net reproduction; r_m = intrinsic rate of natural increase per day; T = mean generation time (days).
[b] Various instars of the prey.
[c] Prey = proto- and deutonymphs.
[d] Prey = eggs only.
[e] Female prey.

pupa. The eggs are elongated ovals and generally are of a pale creamy colour. They are laid singly on the leaf or on the bark, most often in the midst of the mite colony, or in the immediate vicinity. The colour of the larva varies with its age and with the species, from pale cream to dark grey. Searching for the prey at random was considered to be the rule in the absence of webbing (Fleschner, 1950; Putman, 1955). Although this has not been demonstrated, certain chemicals detected by *Stethorus* larvae may function as kairomones, as in phytoseiids (Sabelis and Van de Baan, 1983). After capture and consumption of the mite, there is an increase in the sweeping movements of the head and thorax of the larva and this behaviour favours the discovery of other prey in the vicinity. Larvae at all stages of their development can crawl along the webbing, but the first and second larval instars seem frequently handicapped by dense webbing on trichous host plants. Slow-moving first-stage larvae attack mite eggs, larvae or young nymphs; and they constitute the most vulnerable instar. On the contrary, the third and 4th larval instars are strong, active and voracious; they attack all mite instars and seem unhindered by the webbing. The larvae suck their prey, liquifying the body contents by extra-oral digestion. Cannibalism on eggs, younger larvae or pupae is not uncommon. A resting period corresponds to the repletion of the 4th larval instar and pupation occurs a few hours after attachment to the leaf; the attached larva is sometimes called the prepupa. The pupa is dark coloured; setae are scarce and no wax secretion exists.

Mating can occur 24 h after female emergence in warm areas, and must be repeated for a maximum oviposition rate. Males can be separated from females by the flattened or notched posterior margin of their last abdominal segment. Isolated females can lay unfertile eggs which they often eat. The sex ratio seems to be constant: 1 male for 1 female. In areas of temperate climate, *Stethorus* species hibernate as adults and can have 2 or 3 generations per year (*S. punctillum; S. punctum* (Lec.)). A lifespan exceeding 1 year has been observed but is not common. Activity is continuous in tropical areas (*S. madecassus* Chazeau; *S. pauperculus* Wse.). Some species with a large geographical range may or may not hibernate (*S. gilvifrons* Muls., *S. picipes* Cas., *S. vagans* Blkb). A facultative reproductive diapause induced by short daylength has been demonstrated for *S. picipes.* (Putman, 1955; Bravenboer, 1959; McMurtry et al., 1970; Colburn and Asquith, 1971; Gutierrez and Chazeau, 1972; Raros and Haramoto, 1974; Chazeau, 1974a; McMurtry et al., 1974; Puttaswamy and Channabasavanna, 1977).

The adults can fly actively and aggregate on mite colonies. They chew and eat the whole mite; their preference for large mobile prey has been observed (Chazeau, 1974b, for *S. madecassus*; the preference is questionable, according to Tanigoshi and McMurtry, 1977) as well as the influence of sex on voracity: gravid females eat twice as many prey as males do, sometimes many more. Prey consumption increases with an increase in temperature. A strong positive correlation exists between the number of prey eaten and the number of eggs laid (Chazeau, 1974b). Various degrees of cannibalism have been reported, which can be explained partly by differences in experimental conditions; anyway, adults are less aggressive than fully grown larvae. The ability of *Stethorus* adults to find their prey at low population levels (less than 1 mite per leaf) has been observed (Hull et al., 1977b). Colburn and Asquith (1970) attributed this ability to olfactory attractiveness, but their experimental method was not flawless.

Most *Stethorus* species attack a large number of tetranychid species, but some are more selective in their choice: for example, *S. punctillum*, *S. punctum* and *S. gilvifrons* do not readily feed or oviposit on *Bryobia* (Putman, 1955; McMurtry et al., 1970); *Stethorus fuerschi* Chazeau seems to to be restricted to palm mites (Chazeau, unpublished).

Many authors have emphasized the high voracity and good reproductive capacity of *Stethorus.* Development time is also relatively short, though always longer than in the prey. Some numerical and functional responses to increasing spider mite populations have been demonstrated (McMurtry and Johnson, 1966; Hull et al., 1976, 1977a). Capacity to aggregate on mite infestations and to disperse when prey becomes scarce are positive characteristics of these predators. However, they need a minimum level of mite population in order to colonize infested crops successfully, and alternative mite hosts in the vicinity in order to survive following the decline of the target prey.

OLIGOTA (COLEOPTERA, STAPHYLINIDAE)

Oligota Mannerheim constitutes a cosmopolitan coleopterous genus of the family Staphylinidae, subfamily Aleocharinae. More than 170 species have been described. Most of them live in decaying plants or in fungi, in stored products, under the bark of trees and even in bird or ant nests where they may either prey upon mites and small insects, or feed on tiny dead arthropods: little is known about their biology.

The larvae as well as the adults of the species discussed here prey upon tetranychid mites. They are generally classified into the subgenus *Holobus* Solier, which some authors consider a valid genus. Records of their distribution and prey are listed in Table 2.3.3.

The adults are small (1—2 mm) elongated insects, fully sclerotized but

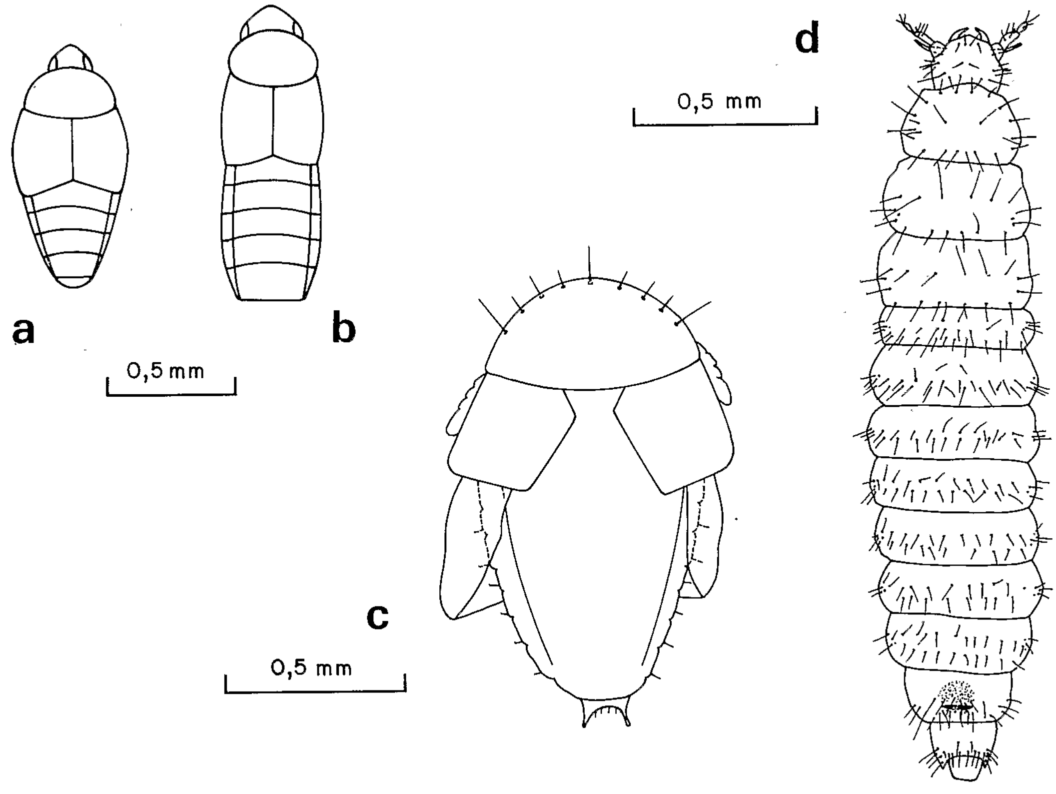

Fig. 2.3.2. *Oligota* (a, b) Body outline of 2 *Oligota* species, (a) *Oligota longula* Cameron, (b) *Oligota inflata* (Mann.) (after Williams, 1976). (c, d) *Oligota oviformis* Casey, (c) pupa, (d) larva (after Moore et al., 1975).

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TABLE 2.3.3.

Some *Oligota* predators of tetranychid mites on various crops

Predator and prey	Crop	Region	Ref.
Oligota barbadorum Frank			
Mononychellus caribbeanae McG., *Mononychellus tanajoa* (Bondar) complex, various tetranychids	Cassava	Barbados	Yaseen et al. (1982)
Oligota chrysopigia Krantz			
tetranychids	—	Tahiti	Coiffait (1976)
tetranychids	—	Samoa	Coiffait (1976)
Oligota fageli Williams			
Mononychellus tanajoa (Bondar) complex	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus urticae Koch	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus lombardinii B. & P.	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus neocaledonicus André	Cassava	Kenya	Yaseen et al. (1982)
Oligota flavicornis (Boisd. & Lac.)			
Panonychus ulmi (Koch)	Fruit trees	Europe	McMurtry et al. (1970)
Panonychus citri (McG.)	—	Japan	McMurtry et al. (1970)
Tetranychus ludeni Zacher	Beans	New Caledonia	Chazeau and Guttierez (1977)
Tetranychus neocaledonicus André	Papaw	New Caledonia	Chazeau and Guttierez (1977)
Tetranychus neocaledonicus André	Cassava	New Caledonia	Chazeau and Guttierez (1977)
Tetranychus neocaledonicus André	Papaw	New Hebrides	Chazeau and Guttierez (1977)
Tetranychus marianae McG.	Ornamentals	New Hebrides	J. Gutierrez (personal communication, 1983)
Tetranychus lambi P. & B.	Coconut palm	Am. Samoa	Chazeau and Guttierez (1977)
Tetranychus neocaledonicus André	Various crops	Madagascar	Gutierrez (1976)
Tetranychus amicus (Mey. & Rod.)	Solanum	La Réunion	J. Gutierrez (personal communication, 1983)
Oligota minuta Cameron			
Mononychellus caribbeanae McG., *Mononychellus tanajoa* (Bondar) complex, various tetranychids	Cassava	The Antilles, Brazil, Bahamas, Columbia, Equador, French Guyana, Peru, Surinam	Yaseen et al. (1982)
Oligota oviformis Casey			
Panonychus citri (McG.)	Citrus	Japan	McMurty et al. (1970)
Tetranychus urticae Koch	Strawberries	California	Oatman et al. (1981)

Oligonychus punicae (Hirst)	Avocado	California	Fleschner (1958)
Eotetranychus sexmaculatus (Riley)	Avocado	California	Fleschner (1958)
Panonychus citri (McG.)	Citrus	California	Fleschner (1958)
Tetranychus urticae Koch	Papaw	Taiwan	Wen and Lee (1981)
Oligota pallidicornis Cameron			
Tetranychus neocaledonicus André	Various crops	Madagascar	Gutierrez (1976)
Mononychellus tanajoa (Bondar) complex	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus urticae Koch	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus lombardinii B. & P.	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus neocaledonicus André	Cassava	Kenya	Yaseen et al. (1982)
Oligota pusillima (Gravenhorst)			
tetranychids	—	Switzerland	McMurtry et al. (1970)
Oligota pygmaea (Solier)			
Mononychellus caribbeannae McG. *Mononychellus tanajoa* (Bondar) complex, various tetranychids	Cassava	Columbia, Mexico, Peru	Yaseen et al. (1982)
tetranychids	Apple	Chile	Gonzalez (1971)
Oligota sp.			
Panonychus ulmi (Koch)	Fruit trees	Japan	McMurtry et al. (1970)

rather flimsy. The colour is generally black or dark brown, but some species have reddish or yellowish elytra, legs or head appendices. The abdomen projects beyond the short elytra, and is freqently curved upwards.

Within the subfamily, adults of the *Oligota* species are distinguished by their four-segmented tarsi, ten-segmented antennae, widely separated mesocoxae, and hind coxae with a lamella covering the base of the femur. *Holobus* species are separated from other *Oligota* by their broad general shape, conical abdomen, deeply divided labrum, entire prementum lobe and simple mandible (Williams, 1976). Species identification involves the observation of the general shape and colour, body sculpture, maxillary palps, and genitalia, especially the male aedeagus, as the spermatheca is often not sclerotized. Dissecting and mounting techniques are similar to those for *Stethorus*; a permanent mount of the aedeagus in Euparal or Canada balsam can be made on a piece of celluloid (Williams, 1976).

Only a few works deal with the morphology of the immature instars. In *Oligota oviformis* Casey, as in *Oligota flavicornis* Boisduval & Lacordaire, the fully grown larva is about 2 mm long, elongated; the body is soft, pale coloured, with no distinct sclerites; the 8th abdominal tergite bears a dorsal tumid osmeterium, which might play a protective role, possibly by producing a repulsive smell. The pupa of *O. oviformis* is enclosed in a cocoon formed of silk sheets. The body is oviform and soft. Setae are scarce, and the head is covered by the pronotum. The 8th visible abdominal segment bears a bidentate terminal appendix (Moore et al., 1975). Adults, larva and pupa are represented in Fig. 2.3.2.

Biological data available for *O. oviformis* and *O. flavicornis* are summarized in Table 2.3.4. Both species pass through 6 immature stages: the egg, 3 larval stages, the prepupa and the pupa. As pupation takes place in the ground, prepupae and pupae can be destroyed by agricultural practices. In England, adults of the second generation may overwinter (Collyer, 1953).

In tropical areas, development seems to be continuous, but no precise study has been conducted. *O. flavicornis* and *Oligota pallidicornis* Cameron have been observed preying upon all stages of the mites in Madagascar (Gutierrez, 1976), but they attack the active instars more readily than the eggs. The larvae suck their prey and several regurgitations are commonly observed before the rejection of the dead mite; the adults chew and eat the whole prey (Collyer, 1953).

TABLE 2.3.4

Some biological parameters[a] observed for 2 species of *Oligota* predators of tetranychid mites (mean in roman type; range in italics)

Predator: Prey:	*Oligota flavicornis* (B. & L.) on *Panonychus ulmi* (K.)	*Oligota oviformis* (Cas.) on tetranychids
Temperature (°C)	(*Not recorded*)	27
Development time (days)	28	*21–30*
Total progeny (eggs)	*40–50*	> 300
Longevity of adults (days)	35	30[b]
No. of prey consumed during development (mites per day)	—	20
No. of prey consumed by adults (mites per day)	—	10

From Collyer (1953) and McMurtry et al. (1970)
[a] Values of R_0, r_m, T not available.
[b] Oviposition period only.

OTHER COLEOPTERA

Apart from *Saula japonica* Gorham (Endomychidae) which has proved to be an important predator of *Panonychus citri* (McGregor) in Japan, reports of Coleoptera attacking spider mites concern many species of the tribes Coccinellini, Chilocorini and Scymnini (Coccinellidae). Polyphagy is not uncommon in Coccinellini: tetranychids never constitute the favourite prey. The occurrence of these coccinellids is irregular and they are not considered to be primary predators of spider mites (McMurtry et al., 1970; Gonzalez, 1971).

THYSANOPTERA

Thysanoptera are small, elongated and generally winged insects. Asymmetrical piercing mouthparts and protrusible tarsal bladders are major characteristics of the order. About 4000 species of thrips have been recorded: they are phytophagous, pollinophagous, mycetophagous, predaceous or general feeders.

Only 3 families contain a small number of species which prey upon spider mites. They can be classified using the following much simplified key:

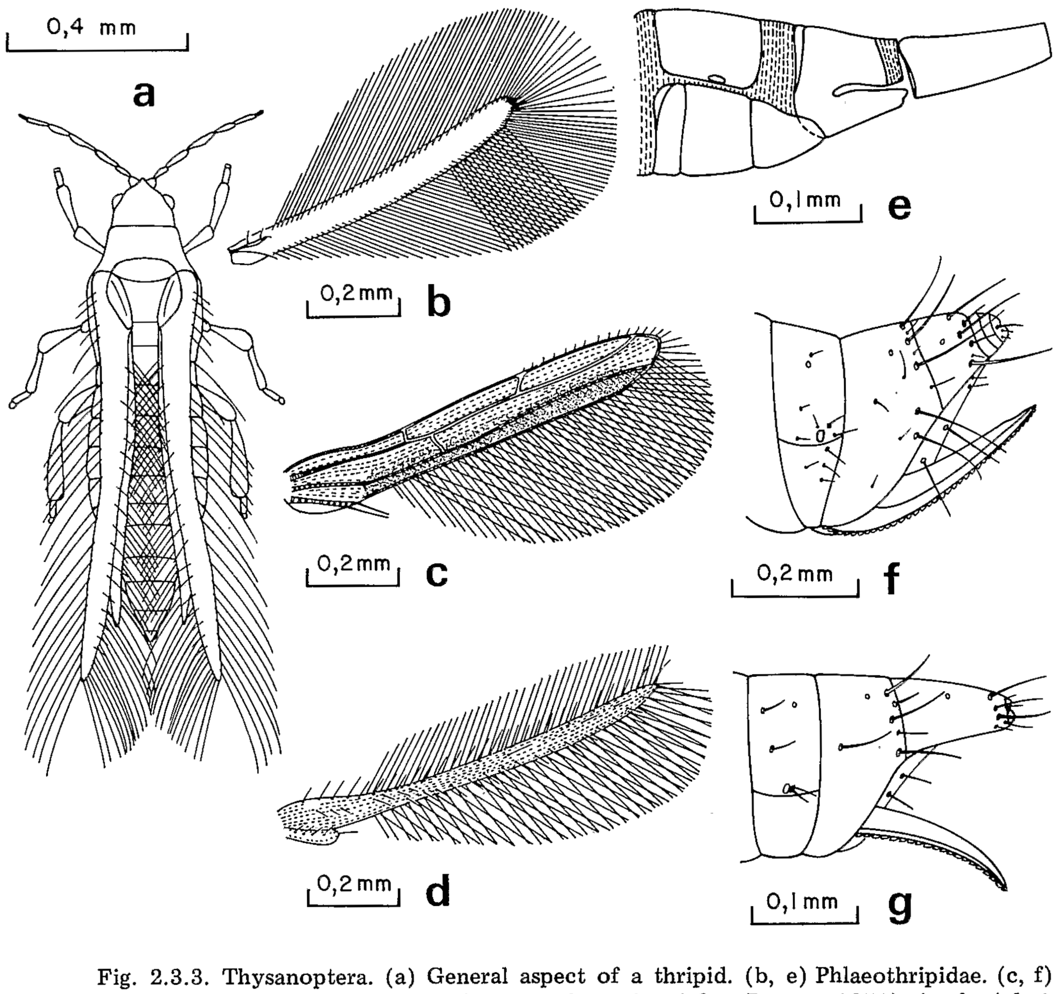

Fig. 2.3.3. Thysanoptera. (a) General aspect of a thripid. (b, e) Phlaeothripidae. (c, f) Aeolothripidae. (d, g) Thripidae (b, c, d) fore-wing (after Pesson, 1951). (e, f, g) last abdominal segments of female (after Pesson, 1951 and Reed, 1970).

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no ovipositor in females; apex of abdomen tubular in both sexes: sub-order Tubulifera: family Phlaeothripidae

saw-like ovipositor present in females; apex of abdomen bluntly rounded in males: sub-order Terebrantia

— ovipositor pointing upwards; broad wings: family Aeolothripidae

— ovipositor pointing downwards; narrow, accuminate wings; family Thripidae.

Abdomen and wings characteristic of these families are represented in Fig. 2.3.3.

Thrips should be preserved according to the following method (A. Bournier, personal communication, 1982). Collected thrips must be kept for 2 weeks at 20—30°C in 10% ethanol with 1‰ liquid detergent. The abdomen is then perforated between segments III and IV, and dehydratation is achieved by 3 successive baths in 35%, 70% and 95% ethanol (30 min each). After immersion for 1 min in lavender oil, specimens are mounted on a slide in Canada balsam for examination.

Records, distribution and prey of Thysanoptera which are predators of tetranychids are listed in Tables 2.3.5 and 2.3.6. This list is by no means exhaustive. There exist many other records of predation on spider mites of minor economic interest. It is likely that many predaceous thrips can achieve complete development on spider mites, even if this prey is not the most suitable. Other Thysanoptera which have non-specialized feeding habits sometimes act as efficient predators of spider mite eggs; this is the case for 2 enemies of *Panonychus ulmi* (Koch), the phlaeothripid *Leptothrips mali* (Fitch) in the U.S.A. (Horsburgh and Asquith, 1968b), and the 'phytophagous' thripid *Thrips tabaci* Lindemann in Europe, Canada, and the U.S.A. (McMurtry et al., 1970).

Development includes 5 or 6 stages before the imago. The eggs are reniform and laid in the plant tissues (Terebrantia), or oval and exposed (Tubulifera). Two mobile wingless instars (generally called nymphs) resemble the adult in their morphology and habits. The resting stages are a prepupa and one (Terebrantia) or two (Tubulifera) pupae. Wing-pads appear in the prepupa (Terebrantia) or in the first pupa (Tubulifera). *Aeolothrips* and some other Terebrantia pupate in a silky cocoon secreted by the second mobile nymph (Pesson, 1951). Thelytokous or arrhenotokous parthenogenesis frequently occurs throughout the order.

The biology of 4 acariphagous thrips (*L. mali* and *Haplothrips faurei* Hood, Phlaeothripidae; *Aeolothrips intermedius* Bagnall, Aeolothripidae; *Scolothrips sexmaculatus* ((Pergande), Thripidae) has been studied; some results are summarized in Table 2.3.7. Comparing these data is not easy, since temperatures, humidities and photoperiods are not the same. However, the studies clearly show various degrees of specialization on mites. *A. intermedius* is primarily a predator of phytophagous thrips, but it can also develop on spider mites, in which case slower development is observed: 23.7 days on *P. ulmi*, 18 days on *T. tabaci* at 26°C; in both cases, consumption of vegetal tissues is necessary to reach sexual maturity. *H. faurei*, a predator of moth eggs, also feeds readily on tetranychid eggs, but not on mobile prey as it lacks the grasping behaviour; fresh pollen or leaf juices are used only to prevent starvation when animal food is not available. *S. sexmaculatus* appears to be much more specialized on spider mites, and the silk threads of the latter are even utilized by the predator to trace the mites (Putman, 1965; Bournier et al., 1978, 1979; Gilstrap and Oatman, 1976).

Eggs are completely consumed, but other instars of the mite are only partially sucked; this behaviour increases the number of prey killed, and so improves the predation efficiency: *A. intermedius* has been reported to kill up to 68 adults of *P. ulmi* during developmental time at 26°C (Bournier et al., 1979). Cannibalism is common in this species, but appears only during

TABLE 2.3.5

Some phlaeothripid and aeolothripid predators of tetranychid mites on various crops

Predator and prey	Crop	Region	Ref.
Phlaeothripidae			
Cryptothrips nigripes Reut.			
Tetranychus urticae Koch	(Hibernation sites)	East Germany	McMurtry et al. (1970)
Haplothrips faurei Hood			
Panonychus ulmi (Koch)	Apple	Canada	McMurtry et al. (1970)
Panonychus ulmi (Koch)	Peach	Canada	Putman and Herne (1966)
Bryobia arborea Morgan	Peach	Canada	Putman and Herne (1966)
Haplothrips subtilissimus (Hal.)			
Eotetranychus pruni (Oud.)	Fruit trees	Kirgizia	Kartasheva and Lesteva (1979)
Panonychus ulmi (Koch)	Apple	U.S.A.	Parrella et al. (1981)
Leptothrips mali (Fitch)			
Panonychus ulmi (Koch)	Apple	U.S.A.	Horsburg and Asquith (1968b)
Aeolothripidae			
Aeolothrips fasciatus (L.)			
Panonychus ulmi (Koch)	Peach	Canada	Putman and Herne (1966)
Tetranychus urticae Koch	Peach	Canada	Putman and Herne (1966)
Aeolothrips melaleucus (Hal.)			
Panonychus ulmi (Koch)	Apple	U.S.A.	Horsburgh and Asquith (1968b)
Panonychus ulmi (Koch)	Peach	Canada	Putman and Herne (1966)
Tetranychus urticae Koch	Peach	Canada	Putman and Herne (1966)

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TABLE 2.3.6

Some thripid predators of tetranychid mites on various crops

Predator and prey	Crop	Region	Ref.
Parascolothrips priesneri Mound			
Tetranychus atlanticus (McG.)	Apple	Iraq	Mound (1967)
Perissothrips brevicornis Bournier			
Eotetranychus savanae Gutierrez	*Vernonia* sp.	Madagascar	J. Gutierrez (personal communication, 1983)
Scolothrips hartwigi Priesner			
Tetranychus neocaledonicus André	Choyote	La Réunion	J. Gutierrez (personal communication, 1983)
Tetranychus neocaledonicus André	Papaw	Madagascar	J. Gutierrez (personal communication, 1983)
Tetranychus neocaledonicus André	Egg-plant	Seychelles	J. Gutierrez (personal communication, 1983)
Eotetranychus smithi (P. & B.)	Rose	Seychelles	J. Gutierrez (personal communication, 1983)
Tetranychus roseus Gutierrez	*Medemia* palm	Madagascar	J. Gutierrez (personal communication, 1983)
Scolothrips indicus Priesner			
Oligonychus indicus (Hirst)	Sorghum	India	Reddy and Jagadish (1977)
Panonychus ulmi (Koch)	Fruit trees	India	Reddy and Jagadish (1977)
Tetranychus ludeni Zacher	Egg-plants, beans	India	Reddy and Jagadish (1977)
Tetranychus urticae Koch	Beans	Thailand	Kantaratanakul et al. (1979)
Scolothrips longicornis Priesner			
Tetranychus urticae Koch	Beans	East Germany	McMurtry et al. (1970)
tetranychids	Fruit trees	Austria	McMurtry et al. (1970)
Scolothrips pallidus (Beach)			
Tetranychus marianae McG.	Sweet potato	New Hebrides	J. Gutierrez (personal communication, 1983)
Tetranychus neocaledonicus André	Cassava	Fiji	J. Gutierrez (personal communication, 1983)
Tetranychus lambi P. & B.	Cassava	Fiji	J. Gutierrez (personal communication, 1983)
Oligonychus biharensis (Hirst)	Breadfruit	Am. Samoa	J. Gutierrez (personal communication, 1983)
Tetranychus tumidus Banks	Egg-plant	Am. Samoa	J. Gutierrez (personal communication, 1983)
Tetranychus yusti McG.	Cassava	Tahiti	J. Gutierrez (personal communication, 1983)
Scolothrips sexmaculatus (Pergande)			
Eotetranychus sexmaculatus (Riley)	Citrus	North America	McMurtry et al. (1970)
Oligonychus punicae (Hirst)	Avocado	California	McMurtry et al. (1970)
Panonychus citri (McG.)	Citrus	California	McMurtry et al. (1970)
Panonychus ulmi (Koch)	Apple	North America	McMurtry et al. (1970)

Tetranychus urticae Koch	Strawberries	California	McMurtry et al. (1970)
tetranychids	Melon, walnuts, cotton	North America	McMurtry et al. (1970)
Tetranychus kanzawai Kishida	—	Japan	McMurtry et al. (1970)
Scolothrips sp.			
Tetranychus neocaledonicus André	Giant taro	New Hebrides	J. Gutierrez (personal communication, 1983)
Scolothrips sp.			
Mononychellus tanajoa (Bondar) complex	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus urticae Koch	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus lombardinii B. & P	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus neocaledonicus André	Cassava	Kenya	Yaseen et al. (1982)

TABLE 2.3.7

Some biological parameters observed for 4 species of thrip predators of tetranychid mites (mean in roman type; range in italics)

Predator: Prey:	*Leptothrips mali* (Fit.) on *Panonychus ulmi* (K.)	*Haplothrips faurei* Hood on *Panonychus ulmi* (K.)	*Aeolothrips intermedius* Bag. on *Thrips tabaci* Lin.	*Scolothrips sexmaculatus* (Per.) on *Tetranychus pacificus* McG.	
Temperature (°C)	23.9	24	26	23.9	29.4
Development time (days)	25.6	*8—10*[a]	*17—19*	23.1	13.6
Length of preoviposition period (days)	*5—7*	—	*2.5—4.5*	—	<1
Total progeny (eggs)	*12—45*[c]	3.3[b]	29[c]	220[c]	242[c]
Longevity of female (days)	*36—54*	>16	21	49	46.2
No. of prey consumed during development (eggs)	—	143	—	Female 68/male 49	Female 64/male 39
No. of prey consumed by ovipositing females (eggs)	—	44[b]	—	783[c]	1853[c]
r_m (per day)	—	—	—	0.155	0.232

From Parrella et al. (1982), Putman (1965), Bournier et al. (1978, 1979) and Gilstrap and Oatman (1976).
[a]From first nymph to adult.
[b]Per day.
[c]Per lifespan.

periods of starvation in *S. sexmaculatus* and can be considered as a positive survival factor.

S. sexmaculatus and *A. intermedius* are arrhenotokous species. After mating, sex ratios of 1 male to 8 females, and 1 male to 1 female have been observed, respectively (Gilstrap and Oatman, 1976; Bournier et al., 1978).

HETEROPTERA

The Heteroptera which attack spider mites belong predominantly to the families Anthocoridae and Miridae. *Himacerus apterus* (Fabr.) (Nabidae) in Europe, and *Geocoris* sp. (Lygaeidae) in North America are facultative predators of spider mites, but they seem to be of secondary importance (McMurtry et al., 1970).

Anthocorids and mirids are fragile, medium-sized bugs, classified among the Cimicoidea (Fig. 2.3.4). They can be easily sorted as follows:

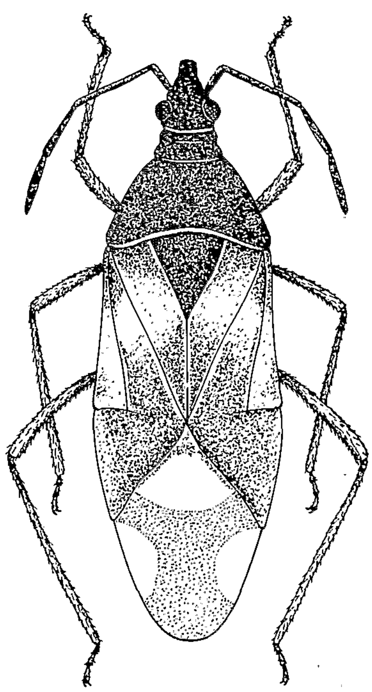
— hemelytron membrane with 1 or 2 closed cells near the cuneus; ocelli absent: Miridae

— no cell near the cuneus; ocelli present: Anthocoridae

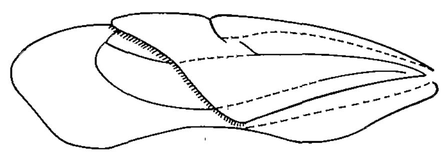
Some anthocorid and mirid predators of tetranychid mites are listed in Tables 2.3.8 and 2.3.9, respectively. Biological data available for some species are given for purposes of reference in Table 2.3.10, but the lack of experimental standards does not allow easy comparisons between the species.

The development includes 6 immature stages: the egg and 5 larval stages. The larvae resemble the adult in their morphology and ecology, but lack wings, whereas the adults can fly actively. Species of cold or temperate climates are univoltine (*Blepharidopterus angulatus* (Fall.) in English orchards) or can have 2 generations per year (*Hyaliodes harti* Knight in North America, *Malacocoris chlorizans* in Europe). Most mirids hibernate as eggs, anthocorids

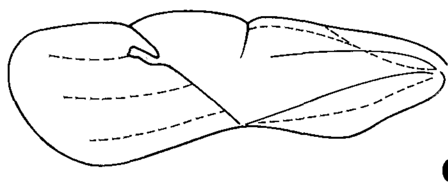
a



b



c



0,2 mm

Fig. 2.3.4. Heteroptera. (a) *Anthocoris nemorum* (L.), general aspect. (b, c) Forewing. (b) Miridae. (c) Anthocoridae (after Poisson, 1951).

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TABLE 2.3.8

Some anthocorid predators of tetranychid mites on various crops

Predator and prey	Crop	Region	Ref.
Anthocoris musculus Say			
Panonychus ulmi (Koch)	—	Canada	McMurtry et al. (1970)
Anthocoris nemoralis (F.)			
Panonychus ulmi (Koch)	Fruit trees	Germany	Steiner (1980)
Anthocoris nemorum (L.)			
Panonychus ulmi (Koch)	Fruit trees	Europe	McMurtry et al. (1970)
Tetranychus urticae Koch	Beans	Europe	McMurtry et al. (1970)
Anthocoris pilosus Yakovlev			
Eotetranychus pruni (Oud.)	Fruit trees	Kirgizia	Kartasheva and Lesteva (1979)
Anthocoris sp.			
Tetranychus kanzawai Kishida	—	Japan	McMurtry et al. (1970)
Panonychus ulmi (Koch)	Fruit trees	Japan	McMurtry et al. (1970)
Cardiastethus sp.			
Tetranychus neocaledonicus André	Choyote	Madagascar	J. Gutierrez (personal communication, 1983)
Clamidiastethus sp.			
Mononychellus caribbeanae McG., *Mononychellus tanajoa* (Bondar) complex, various tetranychids	Cassava	French Guyana	Yaseen et al. (1982)
Orius albidipennis (Reut.)			
tetranychids	Corn and cotton	Egypt	Tawfik and Ata (1973a)
Orius insidiosus (Say)			
Tetranychus urticae Koch	Melons, hops, strawberries	North America	McMurtry et al. (1970)
Panonychus ulmi (Koch)	Fruit trees	North America	McMurtry et al. (1970)
Panonychus citri (McG.)	Citrus	North America	McMurtry et al. (1970)
Orius laevigatus (Fieber)			
Panonychus ulmi (Koch)	—	England	Carayon and Steffan (1959)
Tetranychus urticae Koch	Broad bean	Egypt	Tawfik and Ata (1973b)
tetranychids	Various crops	Egypt	Tawfik and Ata (1973b)
Orius majusculus (Reuter)			
Panonychus ulmi (Koch)	Fruit trees	Europe	Carayon and Steffan (1959)
Orius minutus (L.)			
Panonychus ulmi (Koch)	—	Europe	McMurtry et al. (1970)

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Orius sp.			
Panonychus ulmi (Koch)	Fruit trees	Japan	McMurtry et al. (1970)
Tetranychus kanzawai Kishida	—	Japan	McMurtry et al. (1970)
Orius sp.			
Tetranychus neocaledonicus André	Choyote	Madagascar	J. Gutierrez (personal communication, 1983)
Orius tristicolor (White)			
Tetranychus sp.	Cotton	North America	McMurtry et al. (1970)
Orius vicinus Rib.			
Panonychus ulmi (Koch)	Apple	France	Fauvel et al. (1975)
Wollastoniella gatti Ghauri			
Mononychellus tanajoa (Bondar) complex	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus urticae Koch	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus lombardinii B. & P.	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus neocaledonicus André	Cassava	Kenya	Yaseen et al. (1982)

TABLE 2.3.9

Some mirid predators of tetranychid mites on various crops

Predator and prey	Crop	Region	Ref.
Atractotomus mali (Meyer)			
Panonychus ulmi (Koch)	Fruit trees	Canada	Lord (1971)
Blepharidopterus angulatus (Fall.)			
Panonychus ulmi (Koch)	Fruit trees	Europe	McMurtry et al. (1970)
Campylomma verbasci (Meyer)			
Panonychus ulmi (Koch)	Apple	Europe and	McMurtry et al. (1970)
Bryobia sp.	Apple	North America	McMurtry et al. (1970)
Deraeocoris nebulosus (Uhler)			
Panonychus ulmi (Koch)	Apple	U.S.A.	Horsburgh and Asquith (1968b)
Diaphnocoris pellucida Uhler)			
Panonychus ulmi (Koch)	Apple	North America	McMurtry et al. (1970)
Hyaliodes harti Knight[a]			
Panonychus ulmi (Koch)	Apple	U.S.A.	Horsburgh and Asquith (1968b)
Tetranychus urticae Koch	Apple	U.S.A.	Horsburgh and Asquith (1968a)
Malacocoris chlorizans Panz.			
Panonychus ulmi (Koch)	Fruit trees	Switzerland	Geier and Baggiolini (1952)
Bryobia praetiosa Koch	Fruit trees	Switzerland	Geier and Baggiolini (1952)
Tetranychus urticae Koch	Linden tree	Switzerland	Geier and Baggiolini (1952)
Pilophorus perplexus (D. & S.)			
Panonychus ulmi (Koch)	Fruit trees	Canada	Lord (1971)

[a]Syn.: *H. vitripennis* (Say).

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TABLE 2.3.10
Some biological parameters[a] observed for 4 species of Heteroptera predators of tetranychid mites (mean in roman type; in range in italics)

Predator: Prey:	*Anthocoris nemorum* (L.) on *Panonychus ulmi* (K.)	*Orius albidipennis* (Re.) on tetranychids	*Orius laevigatus* (Fi.) on tetranychids	*Blepharidopterus angulatus* (Fa.) on *Panonychus ulmi* (K.)
Temperature (°C)	20	*27.5—28.9*	*25.5—27.5*	*(Not recorded)*
Development time (days)	34	18.4	17.0	*Nymphs = 30—39*
Length of preoviposition period (days)	—	3.3	5.8	*11—13*
Total progeny (eggs)	> 200	41.3/*19—106*	23.3/*12—52*	43
Longevity of adults (days)	> 100	Female 15.9/Male 14[b]	Female 18/Male 9.7	Female *42—56*/Male *21—28*
No. of prey consumed during development	*3—75*[c]	*230*	288	*690—728*
No. of prey consumed by adults	50[c]	—	—	Female *2520—2940*/Male 630[d]

From Niemczyk (1980), McMurtry et al. (1970), Tawfik and Ata (1973a, b) and Collyer (1952)
[a]Values of R_0, r_m, T not available.
[b]At 25°C.
[c]Female prey per day.
[d]Female prey per lifespan.

as adults. Overwintering eggs are embedded in the bark of trees, and a minimum period of chilling is necessary for hatching (14 weeks at 4.4°C to obtain > 60% hatching in *B. angulatus*) (Muir, 1966). In tropical areas, continuous development and overlapping generations seem to be the rule, and the eggs are generally inserted singly in the plant tissues, near the prey.

The sex ratio (male:female) ranges from 1:1 to 1:1.5 in *Orius albidipennis* (Reut.); in *Orius laevigatus* (Fieber), 1 male to 2 females is the observed ratio in the field; in *B. angulatus*, males are more numerous than females in early summer, but the ratio reverses later in the season (Tawfik and Ata, 1973a,b).

Anthocorids are polyphagous predators, but some *Orius* species are partially phytophagous. Many anthocorids have been reported to feed on Homoptera (aphids, coccids, white flies, leaf-hoppers), Thysanoptera, Lepidoptera (moth eggs and young larvae), Heteroptera (tingids, lygaeids, mirids), larvae of Diptera (gall midges, fruit flies) and of Coleoptera (weevils, ladybirds). Some observations indicate that small prey, like mites, are attacked by the youngest larval instars, whereas the old larvae and the adults prefer larger prey when these are available. Spider mites do not constitute the most suitable prey: a shorter development period and a higher fecundity are observed in *O. albidipennis* when fed with *Gynaikothrips ficorum*: a diet of *Aphis gossypii* doubles the lifespan of *O. laevigatus* females and multiplies by 4 times the number of eggs laid. However, tetranychid diets always allow complete development (Tawfik and Ata, 1973a, b).

Mirids are essentially phytophagous. Among the predaceous species listed in Table 2.3.9, *Atractotomus mali* (Meyer), *Campylomma verbasci* (Meyer) and even *B. angulatus* feed readily on plants; but the larvae of *B. angulatus* cannot survive on a diet of plant juice (Collyer, 1952). Lord (1971) made a precise comparison of these 3 species with *H. harti*, *Diaphnocoris pellucida* Uhler and *Pilophorus perplexus* (D. & S.). He concluded that the number of *P. ulmi* winter eggs consumed by *A. mali* and *C. verbasci* was only half the number consumed by the other species, which is about 250 daily for the adult, and from 20 to 65% of this number for the larvae. It was shown that *H. harti*, *D. pellucida*, *P. perplexus* and *B. angulatus* reached maturity when reared on *P. ulmi* only.

Anthocorids and mirids suck their prey, holding mobile instars with the forelegs if necessary. *Anthocoris nemorum* (L.) can locate spider mite by smell (Mpakagiannis, 1982). Askari and Stern (1972) observed no significant difference between the total number of mobile prey (*Tetranychus pacificus*) killed by *Orius tristicolor* (White) during its life at 25.5°C (about 850), in the absence of light and with a 12 h light regime, but the presence of light doubled the number of eggs consumed. Attacks on other predaceous insects (*Stethorus*, *Oligota*, *Conwentzia*) are not infrequent in *B. angulatus*. Krämer (1961) observed the predation of *A. nemorum* and of *Orius minutus* (L.) on phytoseiid mites.

A. nemorum and *M. chlorizans* are frequently parasitized by a braconid wasp in England (Collyer and Massee, 1958). Cannibalism may occur in most species, but seems to appear only when other sources of food become scarce.

CECIDOMYIIDAE (DIPTERA)

The family Cecidomyiidae includes a great number of small and fragile Nematocera. The larvae are phytophagous, saprophagous or zoophagous. *Lestodiplosis oomeni* Harris is a voracious predator of eriophyid mites on tea in Indonesia, which also attacks brevipalpids and psocids (Oomen, 1982). Species of 3 genera (*Arthrocnodax* Rübsaamen, *Feltiella* Rübsaamen, and

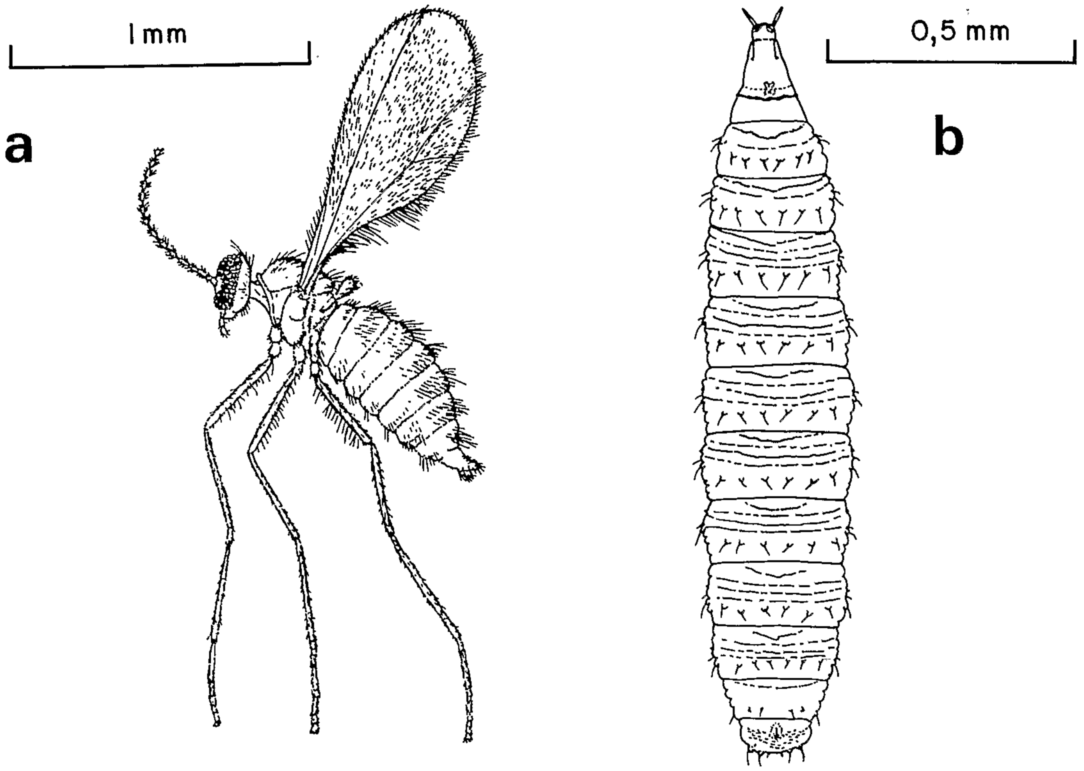

Fig. 2.3.5. Cecidomyiidae. *Therodiplosis persicae* Kieffer. (a) adult, (b) larva (after Roberti, 1954).

Therodiplosis Keiffer) are reputed to prey upon spider mites, but few precise studies of their biology and of their impact on the prey populations are available. Records of their distribution and prey are listed in Table 2.3.11.

General illustrations are given for *Therodiplosis* (Fig. 2.3.5). Species identification relies on a thorough inspection of the antennal segments of males and females, and of the last abdominal segments of females.

The development includes 6 stages: the egg, 4 larval stages, and the pupa. The adults are not predaceous. The slow-moving vermiform larvae attack spider mites at various stages, and the development of *Therodiplosis* and *Feltiella* is completed on this diet. Pupation takes place in a silky cocoon spun on the leaves (observed for *Therodiplosis* and *Lestodiplosis*) or in the soil (frequently observed for *Feltiella*) by the 4th larval instar. Moutia (1958) observed a development time of 18 days at 23°C for *Feltiella* sp., a pre-oviposition period of 2—3 days, a sex ratio of 1 male to 5.6 females, and a lifespan of 5—6 days for adults fed with raisins; the second and third larval instars consumed 9—12 eggs of *Tetranychus marianae* McG. daily, and an equal number of adult mites. Good predating activity against aggregating prey species has been reported for *Arthrocnodax occidentalis* Felt, which can consume 380 mites in 17 days (McMurtry et al., 1970). Hungry *Lestodiplosis* larvae can attack phytoseiids and larvae of their own species (Oomen, 1982).

OTHER DIPTERA

Observations of predation on *T. urticae* and *P. ulmi* by larvae of Syrphidae (especially *Toxomerus geminatus* Say) have been made in Europe and in North America; records also exist of attacks on *P. ulmi* by adult Dolichopodidae in Canada (McMurtry et al., 1970). Syrphidae are considered to become

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TABLE 2.3.11

Some cecidomyiid predators of tetranychid mites on various crops

Predator and prey	Crop	Region	Ref.
Arthrocnodax carolina Felt			
tetranychid eggs	—	England	McMurtry et al. (1970)
Arthrocnodax occidentalis Felt			
Oligonychus punicae (Hirst)	Avocado	California	Fleschner (1958)
Eotetranychus sexmaculatus (Riley)	Strawberry	California	Fleschner (1958)
Tetranychus urticae Koch	Strawberry	California	Oatman et al. (1981)
Arthrocnodax sp.			
tetranychids	Cotton	U.S.A.	McMurtry et al. (1970)
Arthrocnodax sp.			
Mononychellus caribbeanae McG., *Mononychellus tanajoa* (Bondar) complex, various tetranychids	Cassava	Columbia	Yaseen et al. (1982)
Arthrocnodax sp.			
Tetranychus urticae Koch	Fruit trees	Australia	Readshaw (1975)
Panonychus ulmi (Koch)	Fruit trees	Australia	Readshaw (1975)
Feltiella sp.			
Tetranychus marianae McG.	Tomato and egg-plant	Mauritius	Moutia (1958)
Feltiella sp.			
Mononychellus caribbeanae McG., *Mononychellus tanajoa* (Bondar) complex, various tetranychids	Cassava	The Antilles, Bahamas, Columbia, Mexico, Venezuela	Yaseen et al. (1982)
Therodiplosis persicae Kieffer			
Tetranychus neocaledonicus André	Choyote	Madagascar	J. Gutierrez (personal communication, 1983)
Tetranychus neocaledonicus André	Cassava	Papua New Guinea	J. Gutierrez (personal communication, 1983)
Tetranychus neocaledonicus André	Cassava	New Caledonia	J. Gutierrez (personal communication, 1983)
Tetranychus lambi P. & B.	Cassava	New Caledonia	J. Gutierrez (personal communication, 1983)
Tetranychus lambi P. & B.	Cassava	Fiji	J. Gutierrez (personal communication, 1983)
Oligonychus biharensis (Hirst)	Breadfruit	Am. Samoa	J. Gutierrez (personal communication, 1983)
Tetranychus tumidus Banks	Egg-plant	Am. Samoa	J. Gutierrez (personal communication, 1983)
Tetranychus yusti McG.	Cassava	Tahiti	J. Gutierrez (personal communication, 1983)

Therodiplosis sp.			
Mononychellus tanajoa (Bondar) complex	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus urticae Koch	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus lombardinii B. & P.	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus neocaledonicus André	Cassava	Kenya	Yaseen et al. (1982)
Unidentified cecidomyiid			
Panonychus ulmi (Koch)	Fruit trees	England	Collyer (1953)

numerous only at high prey densities. Predation on *P. citri* by adults of the empidid fly *Drapetis micropyga* Melander has been reported in California (Fleschner and Ricker, 1953). As these brachyceran flies are aphidophagous or non-specialized predators, their activity against spider mites is probably not very important.

NEUROPTERA

Insects of the order Neuroptera are easily characterized by the conspicuous wing venation of the adults and the piercing mouthparts of the larvae. The most active predators of spider mites belong to the families Chrysopidae and Coniopterygidae. Some Hemerobiidae (genus *Hemerobius*) have been reported to attack tetranychids in Europe and North America, but appear to have no significant importance. None of these species is specialized on mites (McMurtry et al., 1970).

Chrysopids are brightly coloured insects (size: 10—15 mm), popularly named lacewings. Coniopterygids are much smaller (size: 2—6 mm) and covered with a whitish exudate. The general shape of the larvae and the adult wing venations are illustrated in Fig. 2.3.6.

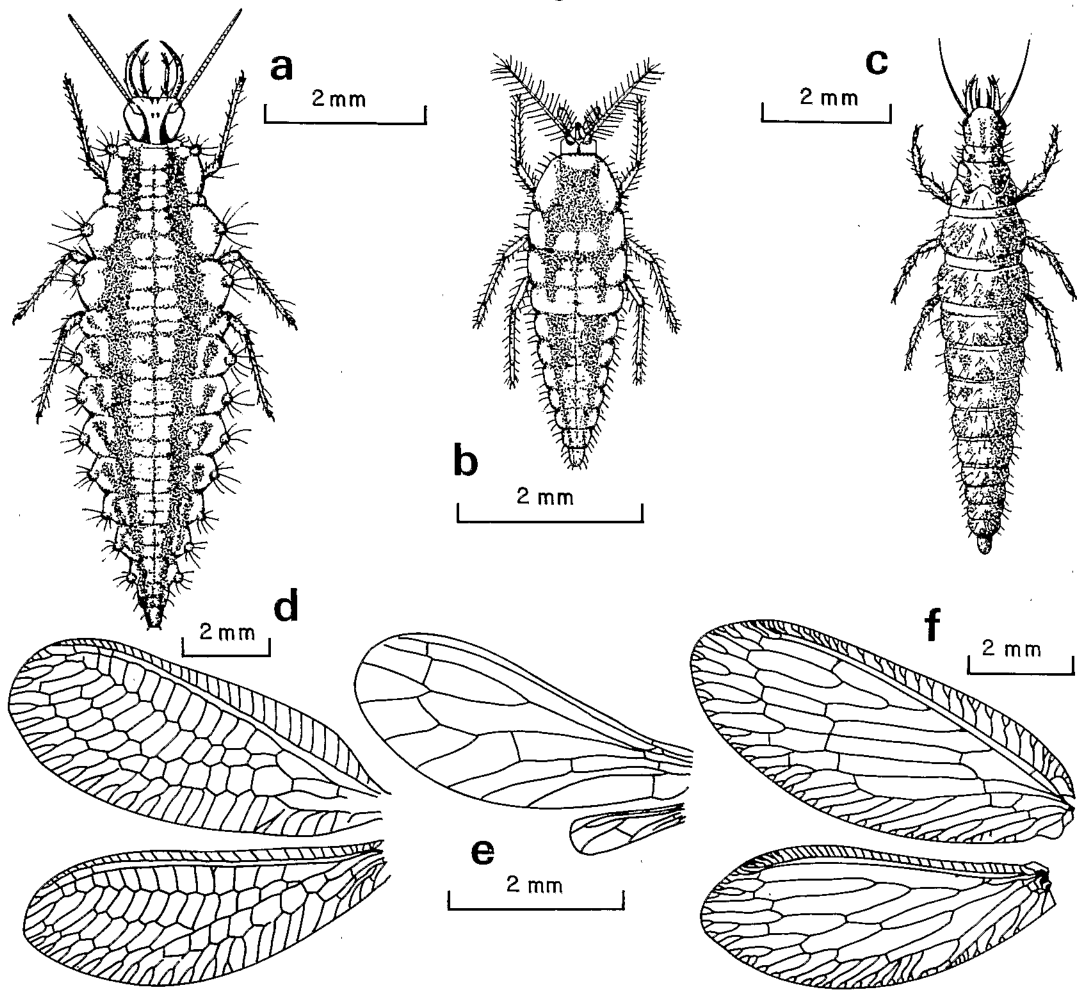

Fig. 2.3.6. Neuroptera. (a, d) Chrysopidae, (b, e) Coniopterygidae, (c, f) Hemerobiidae. (a, b, c) larva (after Imms, 1957 and Berland and Grassé, 1951). (d, e, f) wing venation of adults (after Berland and Grassé, 1951).

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TABLE 2.3.12

Some Neuroptera predators of tetranychid mites on various crops

Predator and prey	Crop	Region	Ref.
Chrysopidae			
Chrysopa carnea Stephens			
Panonychus ulmi (Koch)	Fruit trees	Europe and North America	McMurtry et al. (1970)
Chrysopa lateralis Guérin			
Eotetranychus sexmaculatus (Riley)	Citrus	Florida	McMurtry et al. (1970)
Chrysopa spp.			
Panonychus citri (McG.)	Citrus	Japan	McMurtry et al. (1970)
Panonychus ulmi (Koch)	Fruit trees	Japan	McMurtry et al. (1970)
Coniopterygidae			
Conwentzia pineticola End.			
Panonychus ulmi (Koch)	Fruit trees	Europe	Collyer (1951)
Conwentzia psociformis (Curt.)			
Panonychus ulmi (Koch)	Fruit trees	Europe	Collyer (1951)
Coniopteryx crassicornis Eb. Pet.			
Mononychellus tanajoa (Bondar) complex	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus urticae Koch	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus lombardinii B. & P.	Cassava	Kenya	Yaseen et al. (1982)
Tetranychus neocaledonicus André	Cassava	Kenya	Yaseen et al. (1982)
Coniopteryx vicina Hagen			
Eotetranychus sexmaculatus (Riley)	Citrus	Florida	McMurtry et al. (1970)
Semidalis albata End.			
Panonychus citri (McG.)	Citrus	Japan	McMurtry et al. (1970)
Panonychus ulmi (Koch)	Fruit trees	Japan	McMurtry et al. (1970)

TABLE 2.3.13

Some biological parameters[a] observed for 3 species of Neuroptera predators of tetranychid mites (mean in roman type; range in italics)

Predator: Prey:	*Chrysopa carnea* Ste. on *Panonychus ulmi* (K.)	*Conwentzia pineticola* End. on *Panonychus ulmi* (K.)	*Coniopteryx vicina* Hag. on *Eotetranychus sexmaculatus* (Ril.)
Temperature (°C)	26.7	*(Not recorded)*	26.7
Development time (days)	*13—19 (larva)*	*19—28*	36.4
Fecundity (eggs per day)	13[b]	5	*2—5*
Maximum total progeny (eggs)	—	107	266
No. of prey consumed during development (mites per day, all instars of the prey)	*1000—1500 (L3)*	*30—35 (L3)*	*29—83*[c]

From McMurtry et al. (1970) and Collyer (1951)

[a] Values of R_0, r_m, T not available.

[b] On protein hydrolysate and honey.

[c] On *Panonychus citri* (McG.).

As a rule, the development includes 5 immature stages. The eggs are laid in batches and stuck to the substrate: the stalked eggs of chrysopids are characteristic. The 3 larval instars are active hunters with conspicuous, highly specialized, piercing mouthparts; cannibalism is not uncommon; pupation occurs in a silky cocoon spun by the third larval instar on the leaves or on the bark. The adults of many species are carnivorous, but they chew the prey whereas larvae suck them dry; they have been reported to sometimes prefer liquid nutrients. The insects usually overwinter in the larval or pupal stage in cold or temperate climates, but they may overwinter as adults in the warmest areas; 2 or 3 generations per year have commonly been observed. In tropical areas, development is continuous and generations overlap.

Some chrysopids and coniopterygids which are predators of spider mites are listed in Table 2.3.12. Many other observations exist, some of them from tropical countries, usually alluding to the fact that these insects have a minor beneficial effect. Biological data available for species of the group reared on tetranychids are summarized in Table 2.3.13. These data are not comprehensive. Further observations on *Coniopteryx vicina* Hagen indicate an ovipositing period of 16—26 days at 27°C (McMurtry et al., 1970).

Chrysopidae are mainly aphid predators, but some of them have shown general feeding habits, including consumption of spider mites. Honeydew, pollen and even synthetic diets of protein hydrolysate and honey have been used successfully in rearing ovipositing adults (McMurtry et al., 1970). *Chrysopa carnea* Stephens and a few other *Chrysopa* species can achieve development on a tetranychid diet. Other field observations have proved, on the contrary, that these insects multiply with difficulty on this diet when released as eggs. As a matter of fact, spider mites are not the most adequate source of food for chrysopids, and Fleschner (1958) concluded that their greatest efficiency is observed when they attack mites after the decline of their favourite prey. However, they are useful predators at low levels of mite populations, owing to a very high searching capacity. The antagonistic effect of some *Chrysopa* species on phytoseiid mites was observed by Krämer (1961).

Coniopterygidae show general feeding habits, but they are also reputed to have some value for the control of spider mites. *Conwentzia pineticola* End. is an important predator of *P. ulmi* in England and appears well adapted to this prey, but its occurrence in infested orchards is not constant. *Conwentzia psociformis* (Curt.) readily attacks the mite, but is highly polyphagous (Collyer, 1951). *C. vicina* can feed and develop on *Eotetranychus sexmaculatus* (Riley), but the webbing causes high larval mortality: white flies constitute its favourite prey. In California, other coniopterygid species may sometimes act as important predators of spider mites, but the larvae fail to complete their development, and adults do not oviposit on this exclusive diet (McMurtry et al., 1970).

DERMAPTERA

Dermaptera species (earwigs) are usually omnivorous: many earwigs which are readily carnivorous also feed on dead arthropods, flowers and young foliage.

The predation of *Labidura riparia* (Pallas) (Labiduridae) on *T. urticae* has been reported by Coates (1974) in South Africa; the number of prey eaten by juveniles is rather low (<5 mites per day); adults seldom attack spider mites, even when starved.

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RELATIVE IMPORTANCE OF SPIDER MITE PREDATORS

Croft and Brown (1975) summarized previous reviews on tetranychid—predator systems in deciduous fruit orchards, giving a tentative classification of predators in the following order of descending efficiency: phytoseiids and *Stethorus*; Araneida, thrips and stigmaeids; Hemiptera; Neuroptera; Diptera.

In fact, only a few insect species seem to play a key role in the control of spider mites in Europe and North America: *Stethorus punctillum* Wse., *Stethorus picipes* Cas., *Blepharidopterus angulatus* (Fall.), *Anthocoris musculus* Say, *Haplothrips faurei* Hood and *Scolothrips sexmaculatus* (Per.) (J.A. McMurtry and M. Van de Vrie, personal communication, 1969).

Nevertheless, species belonging to all the taxonomic groups reviewed have been distinguished by authors as 'the most important', 'the dominant' or 'the major' predator: *Stethorus* (McMurtry and Johnson, 1966; Readshaw, 1975); *Oligota* (Gonzalez, 1971); mirids (Collyer, 1952; Readshaw, 1975); anthocorids (Niemczyk, 1980); cecidomyiids and thrips (Oatman et al., 1981); thrips and *Stethorus* (Putman and Herne, 1966). Though the classification proposed by Croft and Brown (1975) is probably of general value, these observations and opinions indicate that apriorism on the relative interest of predators is best avoided when approaching new problems of mite control.

Elements of discussion on the interactions between insect predators are scarce: authors often focus on the alleged 'key' predator and disregard other components of the predator—prey complex. An analysis of such interspecific interactions requires critical experimentation on insect behaviour; results are sometimes conflicting.

Parrella et al. (1980) investigated the interactions between *Leptothrips mali* (Fitch), *Stethorus punctum* Lec. and *Orius insidiosus* (Say) preying upon *P. ulmi*: the association thrips—ladybird resulted in better control than 1 predator alone, when the bug killed and consumed the thrips. Yet McCaffrey and Horsburgh (1982) observed that the anal secretion of *L. mali* larvae efficiently repelled the attacks of well-fed *O. insidiosus*; they concluded that these 2 predators are compatible when prey is abundant. Kantaratanakul et al. (1979) established that *Scolothrips indicus* Evans was at least effective enemy of *T. urticae* when *Stethorus vagans* Blkb. was present, as the thrips were destroyed by the latter. The antagonistic action of *Orius* species against cecidomyiid larvae has also been observed (Fauvel et al., 1975). Competition with phytoseiids and predation upon these mites further complicate the analysis, and generalizations are obviously hazardous.

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