

Chapter 10

Order Plecoptera

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Introduction

Plecoptera is an amphibiotic insect order with a life cycle consisting of three stages: egg, nymph, and imago or adult. Eggs and nymphs are found in freshwater ecosystems, while adults are found in riparian or shoreline terrestrial ecosystems (with few exceptions not present in the Mediterranean Basin). This order is widely distributed on all continents except Antarctica and is present on the main continental islands as well as in Iceland (Hynes, 1988; Fochetti & Tierno de Figueroa, 2008a). It is composed of two suborders, Arctoperlaria and Antarctoperlaria, 17 families (Zwick, 2000; South et al., 2021), and approximately 3800 described species (DeWalt & Ower, 2019; DeWalt et al., 2020). Stoneflies mainly inhabit streams and rivers, but some species can also live in lentic systems (Hynes, 1976). They are very sensitive to physical, chemical, and biological alterations of their habitats, which, together with their low dispersal capacity, make them particularly vulnerable to global change (Fochetti & Tierno de Figueroa, 2006, 2008a; Tierno de Figueroa et al., 2010). Both adults and nymphs contribute significantly to the food webs of freshwater ecosystems (Tierno de Figueroa & López-Rodríguez, 2019), and they exhibit complex and diverse behaviors (Hynes, 1976; Zwick, 1980; Stewart, 1994, 2009; DeWalt et al., 2015).

In their review of the freshwater biodiversity of rivers from the Mediterranean Basin, Tierno de Figueroa et al. (2013) reported 340 stonefly species belonging to 32 genera, seven families, and two superfamilies (Perloidea and Nemouroidea). According to these authors, a high percentage of species, that is, 40.3% of the total (137 species), could be considered endemic to the Mediterranean Basin and that percentage could be significantly higher if species that only slightly exceed the geographical boundaries considered in that study were also included as endemic. Moreover, considering that there are some differences in the boundaries of the Mediterranean Basin between Tierno de Figueroa et al. (2013) and those considered in this book and that there have been many taxonomic and faunal studies on this order of insects in the area, the data presented here differ slightly. Therefore 419 species of Plecoptera can be considered Mediterranean according to the geographic boundaries accounted for in this book. Those species belong to 34 genera (*Agnatina* was not included in the previous paper because only the most western part of Turkey was considered there, and *Zwicknia* was not described as a different genus until 2014). The genera *Afroperlodes*, *Guadalgenus*, *Helenoperla*, and *Tyrrhenoleuctra* are endemic, and *Hemimelaena* and *Eoperla* are nearly endemic to the considered Mediterranean Basin. *Bulgaroperla* has a restricted global distribution, including part of the eastern Mediterranean, and the genera *Besdolus*, *Marthamea*, *Brachyptera*, and *Capnionera* display the greatest specific diversity within the Mediterranean Basin.

General ecology and distribution

Nymphs of stoneflies from the Mediterranean Basin are found in streams from almost sea level [e.g., *Tyrrhenoleuctra tangerina* (Navás, 1922)] to nearly 3000 m a.s.l. (e.g., *Perlodes microcephalus* (Pictet, 1833) or *Isoperla nevada* Aubert, 1952). This suggests that populations are found under a wide array of environmental conditions, which sometimes originate from clearly segregated Plecoptera biocenosis. Mid to lowland biocenosis or those present in temporary streams are mainly characterized by euritherm species and would correspond to the thermophilous association defined by Aubert (1963), while those of higher elevation reaches are dominated by rheophilic, cold-stenotherm species,

corresponding to the orophilous association of [Aubert \(1963\)](#). Due to the specific tolerance ranges of stoneflies to some ecological factors, such as temperature, dissolved oxygen, and salinity, species diversity usually increases with elevation. Within particular stream reaches, nymphs seem to be found more frequently in certain microhabitats, such as those where pebbles or gravels predominate, and less frequently in muddy and sandy substrates ([Tierno de Figueroa et al., 2003](#)). This is probably because in muddy and sandy substrates the very small interstices between particles reduce the water circulation and therefore the available dissolved oxygen.

In their life cycle, stoneflies spend more time in the nymphal stage than in other stages, so factors related to the biotic and abiotic aquatic environment are important for determining the survival and, in general, the fitness of the individuals in each population. Most species are univoltine in the Mediterranean Basin, with some species being semivoltine/merovoltine [e.g., Perlidae as *Perla* spp. or *Dinocras cephalotes* (Curtis, 1827) or Perlodidae as *Guadalgenus franzi* (Aubert, 1963)]. Multivoltinism has not been recorded in any population in the Mediterranean Basin. Nonetheless, because multivoltinism is difficult to distinguish from the coexistence of several cohorts, it is not clear if some species are multivoltine or if different univoltine but temporally delayed cohorts are present in the same stream. This is typical of some species of the *Protonemura* genus, as in *Protonemura gevi* [Tierno de Figueroa & López-Rodríguez, 2010](#), given the particular conditions of the cave this species inhabits (with a constant temperature throughout the year and an absence of light) may play an important role in its developmental pattern ([López-Rodríguez & Tierno de Figueroa, 2012](#)).

To cope with the drought period typical of many temporary streams in the Mediterranean Basin, some strategies have been selected in populations of particular species (see [López-Rodríguez et al., 2017](#)). One of these strategies is the existence of a resting stage in the middle of nymphal development, either diapause or quiescence, usually synchronized with the beginning and the end of the dry period. This allows semivoltine species, such as *G. franzi*, to survive this adverse phase and is usually accompanied by a previous displacement of nymphs to deeper substrates where water remains ([Agüero-Pelegrín & Ferreras-Romero, 2002](#); [López-Rodríguez et al., 2009b](#)). Another relatively common strategy in these environments is the rapid growth rate that can be observed in the nymphs of several univoltine species, mainly in those that develop during the end of winter and/or the spring, that is, in the months prior to the estival drought. This is the case, for instance, for *Brachyptera vera cordubensis* [Berthélemy & Baena, 1984](#) and *Capnioneura glesae* [Berthélemy & Baena, 1984](#) ([López-Rodríguez et al., 2009a](#); [López-Rodríguez et al., 2017](#)). This fast growth ensures that the nymphs have reached the mature stage before conditions become harsh due to the absence of water. In some genera, such as *Capnioneura*, development even occurs sooner in species typically found in temporary streams than in those living in permanent aquatic environments, probably as the result of natural selection favoring nymphs that developed earlier within a population and eggs that hatched before the onset of adverse conditions. Finally, another strategy that has been favored by natural selection under the particular pressures that exist in these streams is the existence of asynchrony in the development of nymphs from the same population. This is reflected in the presence of several overlapping cohorts coexisting in the same stream reach that grow and develop in different months of the year, as occurs in *Tyrrhenoleuctra* cf. *minuta* ([Klapálek, 1901](#)) ([López-Rodríguez et al., 2009a](#)). This asynchronic development is the effect of an extended flight period combined with ovoviviparism (at least in the studied population). The presence of several cohorts in the same population would provide insurance should the drought period start earlier in a particular year. Moreover, other strategies in the adult or egg stages would contribute to the success of Mediterranean stoneflies.

In a review of the biodiversity of Mediterranean rivers, [Tierno de Figueroa et al. \(2013\)](#) found that most species of EPT (Ephemeroptera, Plecoptera, and Trichoptera), both endemic and nonendemic, were univoltine and that several endemic species used diapause as a form of resistance to droughts. Moreover, the largest proportion of both endemic and nonendemic species were *r*-strategists, which could be easily assumed to occur considering stoneflies exclusively. Additionally, [Bonada and Dolédec \(2011\)](#), working on traits of Mediterranean-exclusive genera of macroinvertebrates, found that these taxa exhibited specific traits to cope with the particular flow and climatic conditions occurring in the Mediterranean Basin.

The life cycle and the length and timing of nymphal development depend on the available trophic resources in a particular environment. Species with longer nymphal development may exploit different trophic resources throughout the year, which may differ both qualitatively and quantitatively, while those with a shorter development may have a narrower array of food items to choose from. Overall, the nymphs of Mediterranean stoneflies feed upon a wide assemblage of trophic resources and are fed upon by many other animals. Traditionally, Perloidea have been considered predators, while Nemouroidea have been considered phytophagous–detritivorous, but a wide array of exceptions exists worldwide ([Tierno de Figueroa & López-Rodríguez, 2019](#)). In the Mediterranean Basin, there are also particular records of trophic plasticity, on most occasions related to the resource availability associated with the natural variability in Mediterranean streams and rivers. For instance, *Isoperla morenica* [Tierno de Figueroa & Luzón-Ortega, 2011](#) (formerly included in *I. curtata* [Navás, 1924](#)), belonging to a typical predator family (Perlodidae), behaves as a scraper-grazer in

temporary streams when the availability of certain algae is very high; other Perloidea species also incorporate vegetal matter into their diets under these conditions (López-Rodríguez et al., 2009b).

Due to their wide trophic spectrum, both interspecific and intraspecific stonefly nymphs play different relevant functions in their ecosystems. They are found at different trophic levels and are considered both primary and secondary consumers. As mentioned before, some species in the Mediterranean Basin can be simultaneously predators and primary consumers in the same food web (e.g., López-Rodríguez et al., 2009b). Some species may be found in the detrital-based pathway, consuming leaves and other coarse particulate organic matter, while others are predominantly found in the producer-based pathways, feeding mainly on diatoms or other primary producers. The relative importance of stonefly nymphs as primary consumers in relation to other organisms is thought to be moderate to low, as other organisms have more specialized mouthparts or feeding structures that make them more efficient in that role (e.g., Gastropoda feeding on biofilm with their radula or Gammaridae feeding on leaves with their adapted mouthparts). Nonetheless, stonefly nymphs contribute to maintaining the flux of matter throughout these pathways, and their secondary production is comparable to that of other macroinvertebrates of the same functional feeding group (López-Rodríguez et al., 2009a). On the other hand, nymphs in the upper levels of the food web play a more important role due to their large size and the absence of many other organisms that may compete with them for the same function. Most likely, among lotic macroinvertebrates, only Odonata nymphs may be comparable in terms of size and voracity, but there are few Odonata species that share habitat with stoneflies. In many streams of the Mediterranean Basin, predatory stonefly nymphs are numerically the most dominant macroinvertebrates in the upper levels of the food web (Peralta-Maraver et al., 2017). As such, they may exert an important role as top-down control in these ecosystems, though this has not always been supported, at least when studying experimental macroinvertebrate biocoenoses (López-Rodríguez et al., 2018). Furthermore, stonefly nymphs are an important part of the diet of top-level predators, such as fish; therefore, they contribute to the flow of energy to the uppermost trophic levels in lotic ecosystem food webs.

As mentioned previously, nymphs are sensitive to changes in environmental factors and many species have narrow ranges of tolerance to those factors. This makes stoneflies particularly vulnerable to anthropogenic disturbances. In the framework of the current global change, some of the more important threats stoneflies face are the contamination of middle and lowland reaches due to human activities (agricultural, industrial, etc.), habitat destruction, stream continuity fragmentation, alteration of the environmental conditions both upstream and downstream of barriers (such as dams or hydroelectric power stations), water abstraction for irrigation or human supply, and changes in water temperature due to climate change. The latter causes even high-mountain species in pristine habitats to be endangered as their populations are directly affected by climate warming. In fact, a study assessing the vulnerability of stonefly species across Europe reported that most vulnerable species are found in the Alps, in the Pyrenees, and in the Iberian Peninsula, that is, near the limits of or within the Mediterranean Basin (Tierno de Figueroa et al., 2010). Species with small populations may be facing decline. As pointed out by Fochetti & Tierno de Figueroa (2008a), stoneflies have a high percentage of endemism globally and in the Mediterranean Basin specifically (Tierno de Figueroa et al., 2013). Several species have restricted distribution (Fochetti & Tierno de Figueroa, 2006) and therefore are very exposed to climate change. Indeed, some species are currently known only from their typical localities. Thus the overall vulnerability of this group makes it especially interesting to study the effects of anthropogenic disturbances and, particularly, the consequences of global change. In fact, the monitoring of some population-level parameters or autoecological traits of these organisms may provide a useful tool for managing lotic ecosystems in future climatic and socio-economic scenarios.

Data on the distribution of the Plecoptera genera in the Mediterranean Basin are reported in Table 10.1.

Morphological characteristics needed for identification

Mediterranean Plecoptera nymphs show dull colors, with dark, gray or yellowish tones. The body can be hairless or have bristles of varying lengths and densities. Stonefly nymphs generally have a slender and flattened body, ending in two multiarticulate cerci at the tip of the abdomen. The first stages without wingpads are usually called neanids; individuals are called nymphs with the appearance of wingpads, which become gradually more developed with each molt. Nevertheless, the terms nymph or naiad (or even larvae) are usually used to refer to the complete preimaginal stage.

Head

Nymph head can be prognathous (Perlidae, Perlodidae, and Chloroperlidae), hypognathous (Nemouridae), or somewhat intermediate between the two (Taeniopterygidae, Capniidae, and Leuctridae). Starting from the posterior margin, from a

TABLE 10.1 Distribution of the Plecoptera genera in the Mediterranean area. NW: Mediterranean area of the Iberian Peninsula, France, Italy, and the northwestern Mediterranean islands; NE: Mediterranean areas of the Balkan countries and Greece, including their islands; TC: Mediterranean areas of Turkey and Cyprus; LSIP: Mediterranean area of Lebanon, Syria, Israel and Palestine; and M: Mediterranean area of Maghreb (Morocco, Algeria and Tunisia).

Taxa	NW	NE	TC	LSIP	M
Perlodidae					
<i>Afroperlodes</i> Miron & Zwick, 1973					●
<i>Arcynopteryx</i> Klapálek, 1904	●	●			
<i>Besdolus</i> Ricker, 1952	●	●			
<i>Bulgaroperla</i> Raušer, 1966		●	●		
<i>Dictyogenus</i> Klapálek, 1904	●	●			
<i>Guadalgenus</i> Stark & González del Tánago, 1986	●				
<i>Hemimelaena</i> Klapálek, 1907	●				●
<i>Isogenus</i> Newman, 1833	●				
<i>Perlodes</i> Banks, 1903	●	●	●	●	
<i>Isoperla</i> Banks, 1906	●	●	●	●	●
Perlidae					
<i>Agnentina</i> Klapálek, 1907			●		
<i>Dinocras</i> Klapálek, 1907	●	●			
<i>Eoperla</i> Illies, 1956	●	●			●
<i>Helenoperla</i> Sivec, 1997		●			
<i>Marthamea</i> Klapálek, 1907	●	●	●	●	●
<i>Perla</i> Geoffroy, 1762	●	●	●		●
Chloroperlidae					
<i>Chloroperla</i> Newman, 1836	●	●	●		
<i>Pontoperla</i> Zwick, 1967			●		
<i>Siphonoperla</i> Zwick, 1967	●	●	●	●	●
<i>Xanthoperla</i> Zwick, 1967	●	●	●		
Taeniopterygidae					
<i>Taeniopteryx</i> Pictet, 1842	●	●			
<i>Brachyptera</i> Newport, 1848	●	●	●	●	●
<i>Rhabdiopteryx</i> Klapálek, 1902	●	●	●		
Nemouridae					
<i>Amphinemura</i> Ris, 1902	●	●	●		●
<i>Protonemura</i> Kempny, 1898	●	●	●	●	●
<i>Nemoura</i> Latreille, 1796	●	●	●		●
<i>Nemurella</i> Kempny, 1898	●	●			
Capniidae					
<i>Capnia</i> Pictet, 1841	●	●	●	●	●
<i>Capnioneura</i> Ris, 1905	●	●	●		●

(Continued)

TABLE 10.1 (Continued)

Taxa	NW	NE	TC	LSIP	M
<i>Capnopsis</i> Morton, 1896	●	●	●		●
<i>Zwicknia</i> Murányi, 2014	●	●	●	●	
Leuctridae					
<i>Leuctra</i> Stephens, 1836	●	●	●	●	●
<i>Pachyleuctra</i> Despax, 1929	●				
<i>Tyrrhenoleuctra</i> Consiglio, 1957	●				●

dorsal view, the head shows a metopic suture that originates two postfrontal sutures, which extend up to the base of the antennae, forming the ecdysial or epicranial suture. An occipital fold with taxonomic interest can also be observed in some taxa. Neanids show isolated ommatidia, while nymphs present well-developed compound eyes and (in all the Mediterranean species) three ocelli: one central anterior and two lateral posterior. The antennae are threadlike, formed by a variable number of antennomers. The labrum is a broadly flattened plate hinged to the clypeus or frontoclypeus. Nymphs have chewing mouthparts, with slight differences in morphology inside the order, sometimes reflecting their feeding biology. The mandibles are heavily sclerotized, with both cutting and grinding edges. In the largely carnivorous Perloidea, the mandibles are enlarged and lack a grinding edge, while the cutting edge is formed by two groups of teeth. In contrast, in Nemouroidea (shredders, collectors-gatherers, or scrapers), the mandibles are short and strong and have a well-developed grinding edge. The maxilla has a five-segmented maxillary palp; the lacinia shows a maximum of two apical teeth. The labium has a labial palp consisting of three articles; the glossae and paraglossae are of the same dimension in the Nemouroidea, while the glossae are smaller in the Perloidea.

Thorax

The pro-, meso-, and metanotum are clearly differentiated and longitudinally divided by a suture. The pronotum can bear bristles of taxonomical value on the margin. The legs are long and stout. Both the tibiae and femora can bear fringes of swimming hairs or bristles. The tarsi are three-segmented, with the last segment bearing two terminal claws.

Abdomen

Cylindrical in shape, this structure is formed by 11 metameres, with the first 10 being well developed and the 11th being reduced and modified into two triangular ventral paraprocts and a dorsal lamina, joined to the 10th tergite. Tergites 1 and 2 are separated from their sternites by a membranous area. The remaining tergites (either all or some of them) are joint to the sternites, forming a complete ring. The cerci are always long and filiform.

Gills

The nymphal tracheal system is apneustic, and breathing takes place through the body surface or through gills, which can be differently shaped (finger-like, filamentous, or telescopic). Gill structures may be present in different body regions: on the head (in the postmentum of some Perlodidae) or on the thorax, either in the prosternite (the so-called cervical gills or prosternal gills of the *Protonemura* and *Amphinemura*) or in the pleura (thoracic pleural gills of Perlidae), on the coxae (only in *Taeniopteryx* in the Mediterranean Basin) or on the abdomen (in the anal region in some Perlidae).

Material preparation and preservation

Stonefly nymphs can be collected all year long using different sampling methods. For qualitative studies, a kick sampler can be used, while a Surber or Hess sampler, depending on the type of substrate, is required for quantitative research. These samplers must be placed on the stream bottom, moving the stones upstream (kick) or inside (Surber and Hess)

to allow the nymphs to drift and enter the net. For collecting nymphs from the hyporheic zone, a Bou-Rouch pump can be employed. The collected material can be sorted in the field using a white plastic tray and must then be stored in plastic vials containing preserving liquids, usually 70% alcohol. For better fixation of internal organs, a mixture of 90% alcohol with 2% formaldehyde (40% by volume) can be used. Regarding molecular research, stonefly nymphs must be preserved in 95% to 99% alcohol or, if dealing with RNA, in RNAlater™ (see, for instance, [Tierno de Figueroa & Fochetti, 2014](#)).

The morphological study of neanids and nymphs usually requires observation under a stereomicroscope. Specimens must often be dissected for the study of internal organs or structures. Organs can be mounted on microscope slides using a preserving (fixative) compound (e.g., Hoyer or Faure fixatives) prior to examination under a transmission microscope. Morphological and ultrastructural investigations of anatomic structures can be carried out by scanning and transmission electron microscopy. The use of these approaches requires specific preparation methods (see, for instance, [Fausto et al., 2002](#)).

Stonefly nymphs can be reared in the laboratory. In this regard, simple artificial water courses can be built, consisting of a continuous flow of water in a container, with a refrigerating system to keep the water at a constant or controlled temperature and a pump with an incorporated filter.

A more thorough and detailed treatment of collecting, rearing, preserving, and labeling Plecoptera nymphs can be found in [DeWalt et al. \(2015\)](#).

The study of nymphal feeding can be carried out by analyzing gut contents, dissecting the gut, or clearing the integument with suitable liquids (e.g., Hertwig's liquid) prior to the observation of ingested material through a microscope (for details, see [Tierno de Figueroa & Fochetti, 2001](#)). Data on nymphal trophic ecology can also be based on direct observations in nature or in the laboratory, experimental studies and stable isotope analyses (see, for instance, [Hershey et al., 2006](#)), or studies on digestive enzymatic activity (see, for instance, [López-Rodríguez et al., 2012](#)).

In some studies, such as those dealing with the secondary production of nymphs, dry mass may be necessary. As in other animal groups, dry mass is preferentially obtained from individuals that are preserved in 4% formaldehyde, dried at 60°C for 24 h, desiccated for 1 h and posteriorly weighed with a microbalance (see, for instance, [Benke & Huryn, 2006](#)).

For biometric studies (including those aimed at analyzing the life cycles or the growth rates of nymphs), preservation in 4% formaldehyde is preferred, but individuals preserved in 70% alcohol could also be used.

Keys

The keys presented here are based on those of [Hynes \(1977\)](#), [Consiglio \(1980\)](#), [Sivec et al. \(1988\)](#), [Tierno de Figueroa et al. \(2003\)](#), [Fochetti & Tierno de Figueroa \(2008b\)](#), [Tachet et al. \(2010\)](#) and, mainly, [Zwick \(2004\)](#) as well as the direct observation and study of specimens and original descriptions of some genera. Because the nymphs of many species have not been described yet or, in other cases, no valuable characters allow species differentiation, we have only included keys for families and genera.

Plecoptera: Families

- 1 Glossae reduced, considerably shorter than paraglossae ([Fig. 10.1A](#)); last segment of maxillary palp narrower than previous segments ([Fig. 10.1B](#)) (Superfamily Perloidea) 2
- 1' Glossae and paraglossae with similar lengths ([Fig. 10.1C](#)); last segment of maxillary palp as wide as previous segments ([Fig. 10.1D](#)) (Superfamily Nemouroidea) 4
- 2(1) Thoracic pleural gills absent 3
- 2' Thoracic pleural gills present ([Fig. 10.2](#)) **Perlidae**
- 3(2) Maxillary palpus with apical segment distinctly smaller than the previous segment (approximately 1/3–1/4 wide), needle-like, and set asymmetrically on the previous segment ([Fig. 10.3A](#)); outer margins of the wingpads rounded ([Fig. 10.3B](#)) **Chloroperlidae**
- 3' Maxillary palpus with apical segment only slightly smaller than the previous segment, not needle-like, and set symmetrically on the previous segment ([Fig. 10.1B](#)); outer margins of the wingpads straight ([Fig. 10.3C](#)) **Perlodidae**
- 4(1') Tarsal segment 2 clearly shorter than segment 1 ([Fig. 10.4A](#)) 5
- 4' Tarsal segments progressively longer from 1st to 3rd ([Fig. 10.4B](#)) **Taeniopterygidae**
- 5(4) Body streamlined and cylindrical; extended metathoracic legs not reaching the tip of the abdomen* ([Fig. 10.5A](#)) 6
- 5' Body stout; extended metathoracic legs reaching or surpassing the tip of the abdomen ([Fig. 10.5B](#)) **Nemouridae**

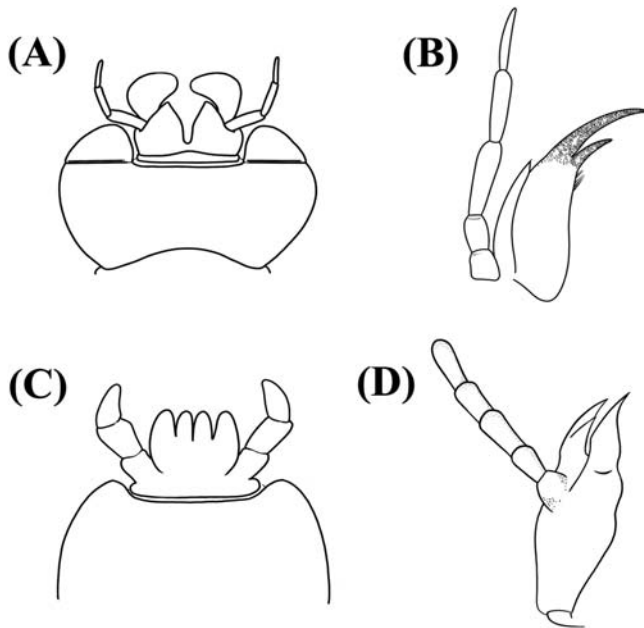


FIGURE 10.1 (A) Labium of a Perloidea; (B) maxilla of a Perloidea; (C) labium of a Nemouroidea; (D) maxilla of a Nemouroidea.



FIGURE 10.2 Photograph of a *Perla* showing its thoracic pleural gills.

- 6(5) Mentum small, not covering the basal part of the maxillae (Fig. 10.6A) **Capniidae**
- 6' Mentum very large, covering the basal part of the maxillae (Fig. 10.6B) **Leuctridae**

*Note: The disposition of mature nymph wingpads is usually employed for distinguishing Nemouridae (with wingpads divergent from the body axis) from Capniidae/Leuctridae (wingpads parallel or subparallel to the body axis). Nevertheless, within Capniidae, the genus *Capnioneura* has slightly divergent wingpads (Fig. 10.17C). However, *Capnioneura* can be easily distinguished from Nemouridae by its glabrous body and cerci, together with the thick basal parts of its cerci (Fig. 10.17E) (as well as the other characters reported in the keys).

Plecoptera: Perlodidae: Genera

(Ten genera and approximately 60 species in the Mediterranean Basin)

- 1 Paraprocts blunt (Fig. 10.7A) (Subfamily Perlodinae) 2
- 1' Paraprocts pointed (Fig. 10.7B) (Subfamily Isoperlinae) ***Isoperla***
- 2(1) Lacinia unidentate (Fig. 10.8A) 3

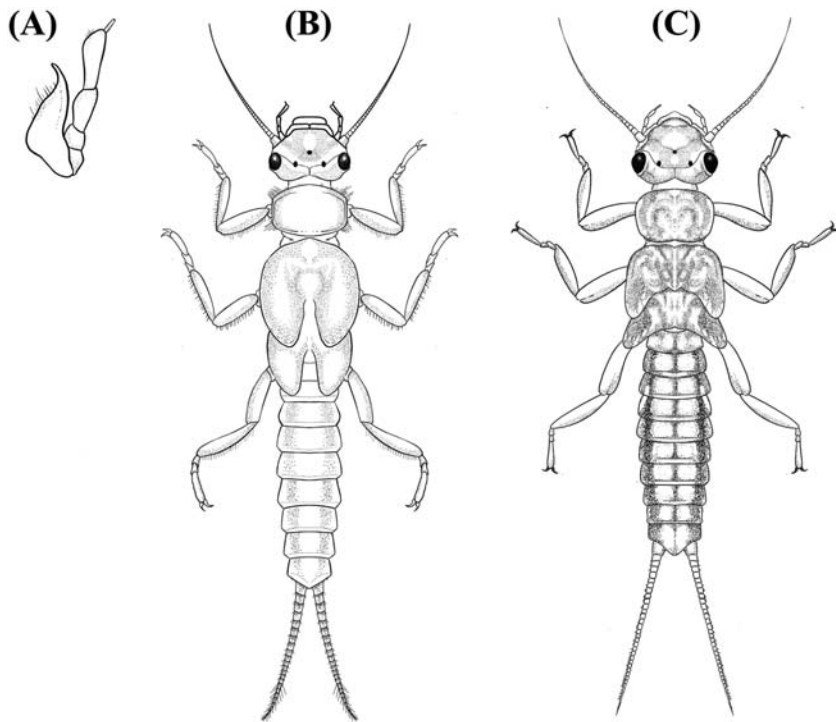


FIGURE 10.3 (A) Maxilla of a Chloroperlidae; (B) habitus of a Chloroperlidae; (C) habitus of a Perlodidae.

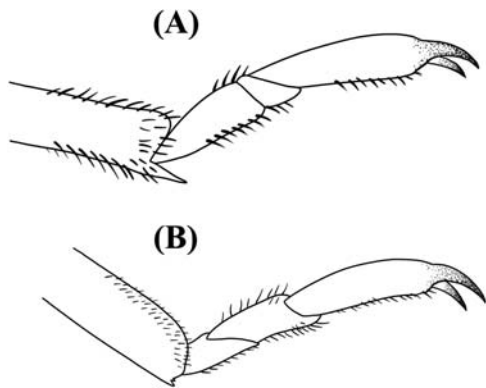


FIGURE 10.4 Distal part of the leg of (A) a Nemouridae; (B) a Taeniopterygidae.

- 2' Lacinia bidentate (with terminal and subterminal teeth) (Fig. 10.8B–F) 4
- 3(2) Head and pronotum hairless *Afroperlodes*
- 3' Head and pronotum with hairs *Hemimelaena*
- 4(2') Short finger-shaped gill on either side of the base of the postmentum absent. Abdominal segments 1 to 4 or 1 to 2 divided into tergite and sternite by a membranous pleura (Fig. 10.9A, B) 5
- 4' Short finger-shaped gill on either side of the base of the postmentum (Fig. 10.9D). Abdominal segments 1 to 3 divided into tergite and sternite by a membranous pleura (Fig. 10.9C) *Arcynopteryx*
- 5(4) Abdominal segments 1 to 4 divided into tergite and sternite (Fig. 10.9A) *Perlodes*
- 5' Abdominal segments 1 to 2 divided into tergite and sternite (Fig. 10.9B) 6
- 6(5') Lacinia with setal fringe along the inner edge beginning immediately next to the apical teeth (Fig. 10.8C–F) 7
- 6' Lacinia with setal fringe along the inner edge clearly separated from the apical teeth (Fig. 10.8B) *Bulgaroperla*
- 7(6) Apical tooth of the lacinia short (approximately 1/3 of the lacinia length); inner margin of the lacinia with many setae (more than 9) (Fig. 10.8D–F) 8
- 7' Apical tooth of the lacinia long (approximately 1/2 of the lacinia length); inner margin of the lacinia with only few setae (approximately 3–4) (Fig. 10.8C) *Guadalgenus*

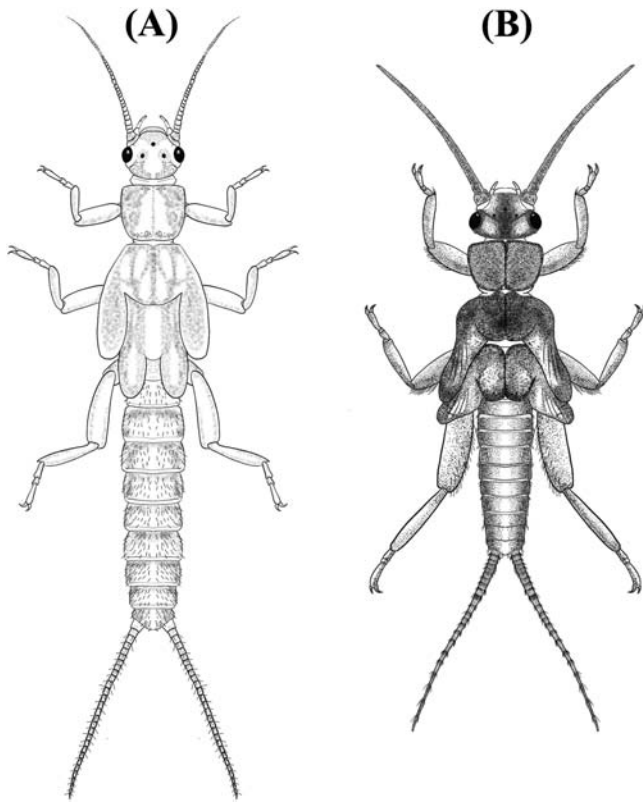


FIGURE 10.5 Habitus of (A) a Leuctridae; (B) a Nemouridae.

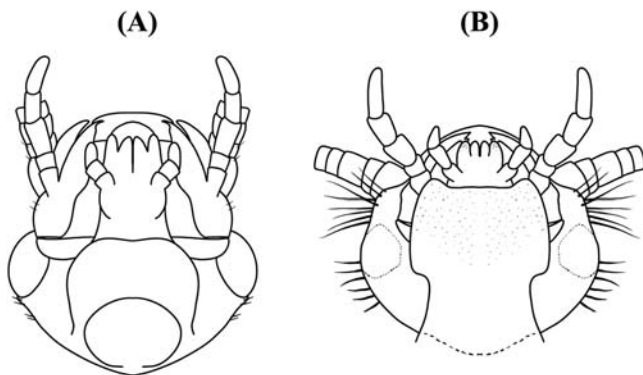


FIGURE 10.6 Head (in ventral view) of (A) a Capniidae; (B) a Leuctridae. Figures redrawn from Zwick (2004).

- 8(7) Inner edge of the lacinia below the subapical tooth with setae in a single long row (Fig. 10.8E, F) 9
- 8' Inner edge of the lacinia below the subapical tooth with setae forming a small patch (Fig. 10.8D) *Besdolus*
- 9(8) Lacinia slender and only slightly notched below the subapical tooth (Fig. 10.8E) *Isogenus*
- 9' Lacinia broad with a distinctive bulge below the subapical tooth (Fig. 10.8F) *Dictyogenus*

Plecoptera: Perlidae: Genera

(Six genera and approximately 21 species in the Mediterranean Basin)

- 1 Postmentum with anterior lobes separated by sutures (Fig. 10.10A) 2
- 1' Postmentum with anterior lobes not separated by sutures (Fig. 10.10B) 3
- 2(1) Occipital fold angled forward (Fig. 10.11A); abdomen without pale bands, with only paired pale spots *Dinocras*
- 2' Occipital fold regularly curved (Fig. 10.11B); abdomen with two more or less complete pale bands *Eoperla*

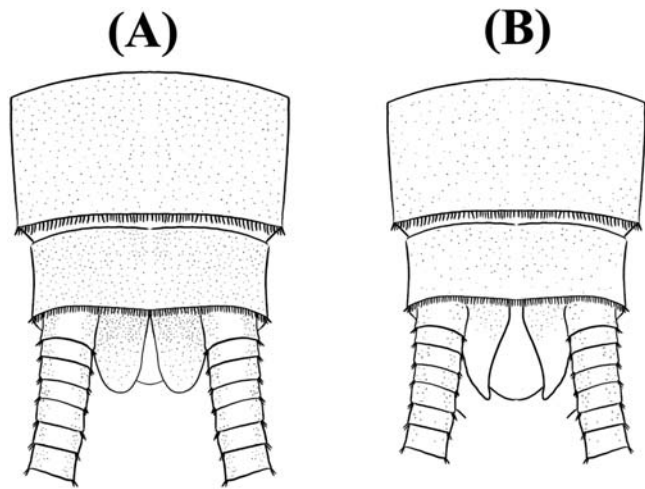


FIGURE 10.7 Abdomen tip of (A) a Perlodinae; (B) an Isoperlinae.

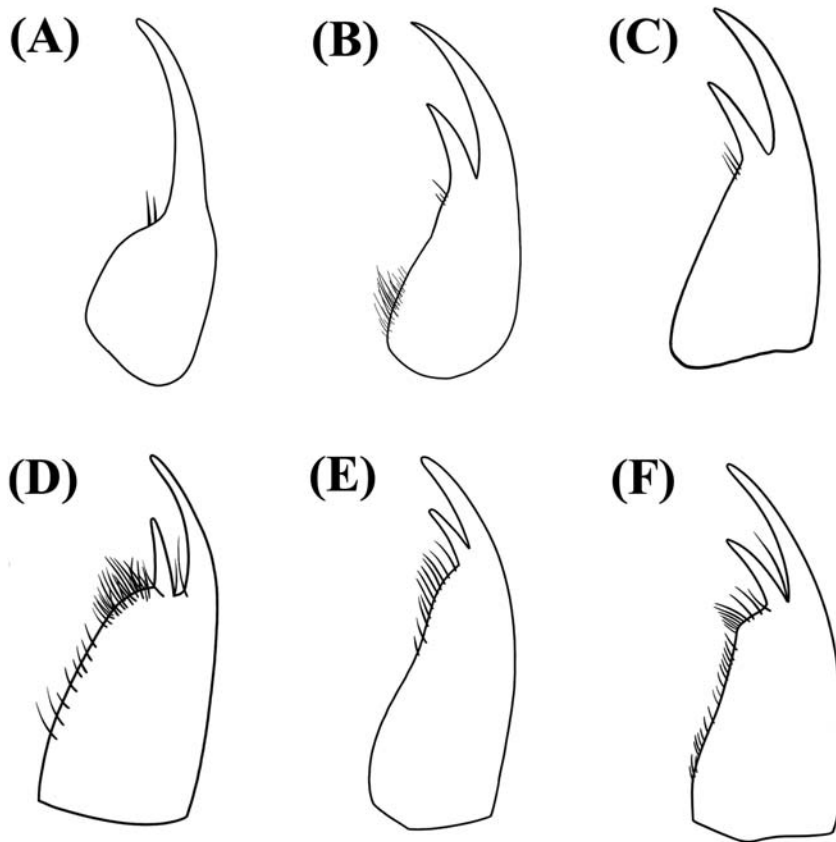


FIGURE 10.8 Lacinia of (A) *Hemimelaena* (similar in *Afroperlodes*); (B) *Bulgaroperla*; (C) *Guadalgenus*; (D) *Besdolus*; (E) *Isogenus*; (F) *Dictyogenus*. Figures B-F redrawn from Zwick (2004).

- 3(1') Occipital fold bent angularly forward behind inner edge of compound eye (Fig. 10.12A, B) 4
- 3' Occipital fold not bent angularly forward behind inner edge of compound eye (Fig. 10.13A) 5
- 4(3) Head with a dark band between the bases of the antennae leaving a pale area in front of the anterior ocellus (Fig. 10.12A) *Marthamea*
- 4' Head with a dark, wide band between the bases of the antennae interrupted in the middle by three light areas (Figs. 10.12B) *Agnentina*

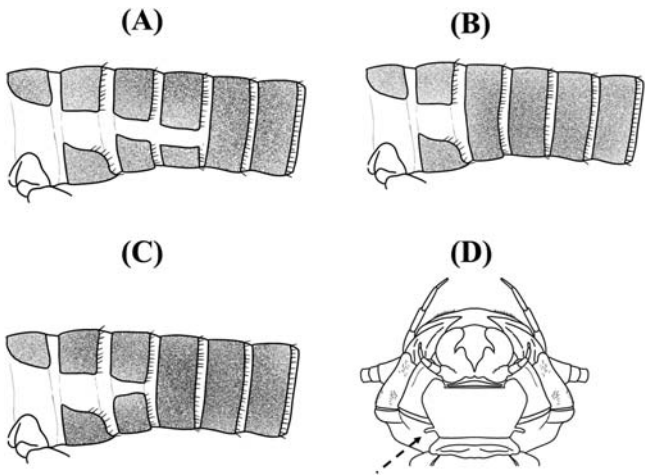


FIGURE 10.9 Proximal part (in lateral view) of the abdomen of different Perlodidae genera showing the abdominal segments: (A) first to fourth segments divided into tergites and sternites; (B) first and second segments divided into tergites and sternites; (C) first to third segments divided into tergites and sternites. (D) Head (in ventral view) of *Arcynopteryx* (finger-shaped gills shown with the arrow).

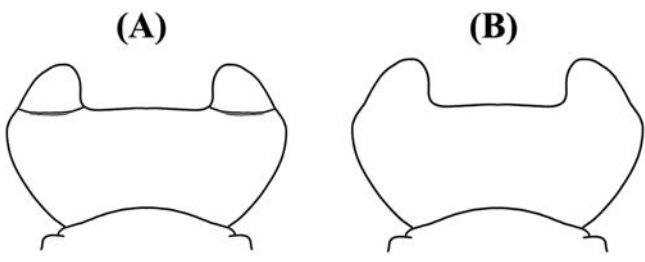


FIGURE 10.10 Postmentum with (A) anterior lobes separated by sutures; (B) anterior lobes not separated by sutures.



FIGURE 10.11 Head (in dorsal view) of (A) *Dinocras*; (B) *Eoperla*.

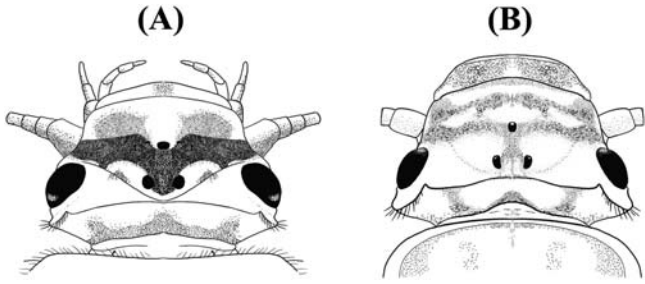


FIGURE 10.12 Head (in dorsal view) of (A) *Marthamea*; (B) *Agnetina*.

5(3') Basal cercus segments with rings of dark spines; pilosity around the cercus segments usually short, half of the segment length (Fig. 10.13B) (without considering those silky, long hairs forming a dorsal fringe, especially in the cercus basal part, exceptionally absent in *Perla bipunctata* Pictet, 1833) ***Perla***
 5' Basal cercus segments without rings of dark spines; cercus surrounded by pilosity, longer than the segment; cerci without dorsal hair fringe (Fig. 10.13C) ***Helenoperla***

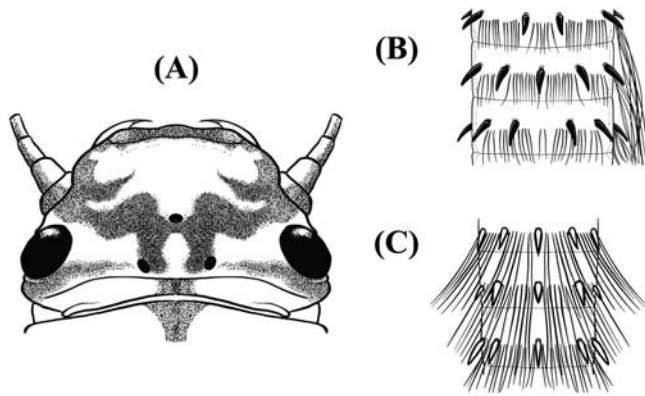


FIGURE 10.13 (A) Head (in dorsal view) of *Perla*. Basal cercus segments of (B) *Perla*; (C) *Helenoperla*. Figures B and C redrawn from Zwick (2004).

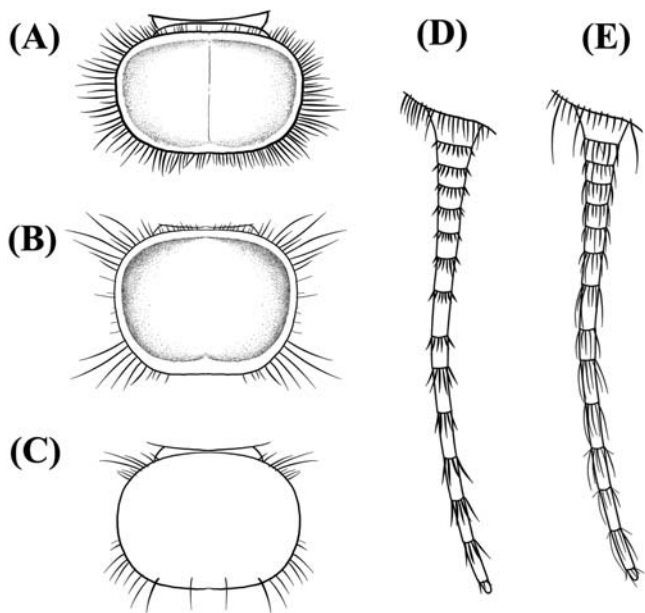


FIGURE 10.14 Pronotum of (A) *Siphonoperla*; (B) *Chloroperla*; (C) *Xanthoperla*. Cercus of (D) *Pontoperla*; (E) *Siphonoperla*. Figures D and E were redrawn and modified from Zwick (2004).

Plecoptera: Chloroperlidae: Genera

(Four genera and approximately 19 species in the Mediterranean Basin)

- 1 Elliptic pronotum, approximately 1.7 times wider than long, and with abundant marginal hairs all around (Fig. 10.14A) 2
- 1' Rectangular pronotum, approximately 1.5 times wider than long, with abundant marginal hairs mainly concentrated on corners, lateral portions hairless (Fig. 10.14B, C) 3
- 2(1) Cercus with setae shorter than the segment over which they extend (Fig. 10.14D) *Pontoperla*
- 2' Cercus with some setae as long as or longer than the segment over which they extend (Fig. 10.14E) *Siphonoperla*
- 3(1') Pronotum with delimiting folds at its front and rear margins and with hairs along them (Fig. 10.14B) *Chloroperla*
- 3' Pronotum without delimiting folds and with only a few hairs along its front and rear margins (Fig. 10.14C) *Xanthoperla*

Plecoptera: Taeniopterygidae: Genera

(Three genera and approximately 36 species in the Mediterranean Basin)

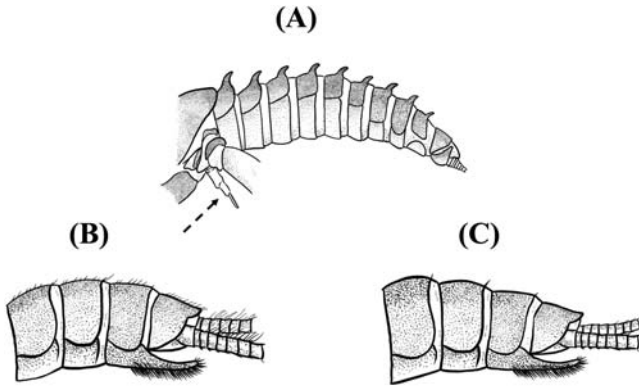


FIGURE 10.15 (A) Abdomen and posterior part of the metathorax (in lateral view) of *Taeniopteryx* (three-segmented coxal gill shown by the arrow). Distal part of the abdomen (in lateral view) of (B) *Brachypteryx*; (C) *Rhabdiopteryx*.

- 1 Coxae without gills; abdominal terga without thorn-like processes 2
- 1' Three-segmented coxal gills present; several abdominal terga with thorn-like sclerotized processes (Fig. 10.15A) *Taeniopteryx*
- 2(1) Abdominal tergites with setae along their distal margins not visible in lateral view; upper side of the cerci with one or more long hairs (Fig. 10.15B); head with a rounded epicranial suture* *Brachypteryx*
- 2' Abdominal tergites with setae along their distal margins visible in lateral view; upper side of the cerci without long hairs (Fig. 10.15C); head with a pointed epicranial suture *Rhabdiopteryx*

Notes: nymphs of some *Brachypteryx* and *Rhabdiopteryx* species have not yet been described, or their characteristics have not been confirmed (see Zwick, 2004). *This last character is not informative for *B. trifasciata* (Pictet, 1832), which has an epicranial suture with an intermediate shape between both genera (Consiglio, 1980; Zwick, 2004).

Plecoptera: Nemouridae: Genera

(Four genera and approximately 131 species in the Mediterranean Basin)

- 1 Cervical gills present (Fig. 10.16A, B) (Subfamily Amphinemurinae) 2
- 1' Cervical gills absent (Subfamily Nemourinae) 3
- 2(1) Cervical gills in two groups (one on each side), each composed of three finger-shaped gills (Fig. 10.16A) *Protonemura*
- 2' Cervical gills in four groups (two on each side), composed of many filamentous gills (Fig. 10.16B) *Amphinemura*
- 3(1') Metathoracic legs with 1st tarsal segment clearly shorter than the 3rd in late instars (Fig. 10.16C) *Nemoura*
- 3' Very long metathoracic legs, with 1st tarsal segment as long as the 3rd in late instars (Fig. 10.16D) *Nemurella*

Plecoptera: Capniidae: Genera

(Four genera and approximately 23 species in the Mediterranean Basin)

- 1 Body with hairs; wingpads parallel or subparallel to each other (Fig. 10.17A, B); cerci not particularly thick at their base and with bristles (Fig. 10.17D) 2
- 1' Body hairless; wingpads long, slender, and slightly divergent (Fig. 10.17C); cerci very thick at their base and hairless (Fig. 10.17E) *Capnioneura*
- 2(1) Body covered by long hairs; eyes with a fringe of long hairs (Fig. 10.17F); wingpads stocky (Fig. 10.17A, F) *Capnopsis*
- 2' Body with short hairs; eyes without a fringe of long hairs; wingpads thin (Fig. 10.17B) *Capnia/Zwicknia**

*Note: The genus *Zwicknia* has been recently erected (Murányi et al., 2014) from a taxon previously belonging to the genus *Capnia* [*C. bifrons* (Newman, 1838)], supported by molecular data and adult morphological characteristics. Nevertheless, no general nymphal characters have been proposed for distinguishing *Zwicknia* from *Capnia*, and those characters employed previously to separate *Capnia bifrons* (currently *Zwicknia bifrons*) from some other *Capnia* species cannot be generally applied to other recently described species of *Zwicknia*, the nymphs of which are unknown in most cases.

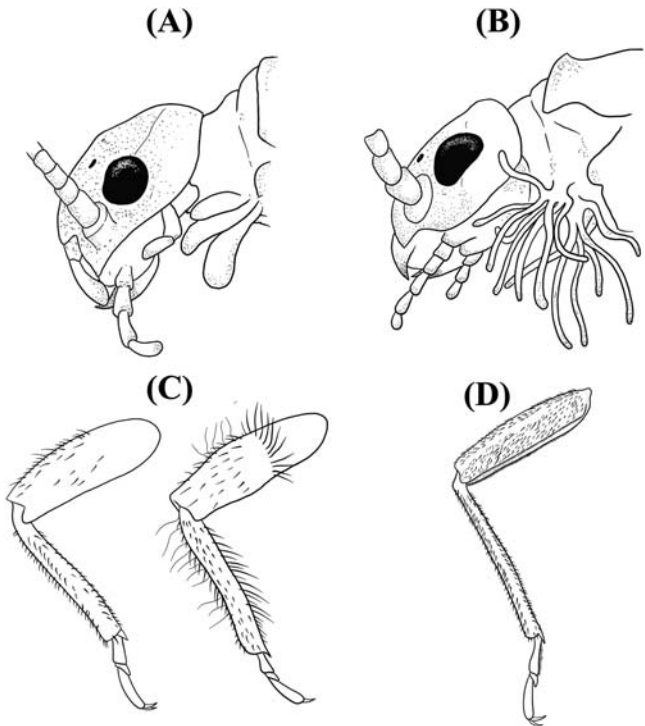


FIGURE 10.16 Head and cervical zone (in lateral view) of (A) *Protonemura*; (B) *Amphinemura*. Metathoracic leg of (C) two different species of *Nemoura*; (D) *Nemurella* in late instars.

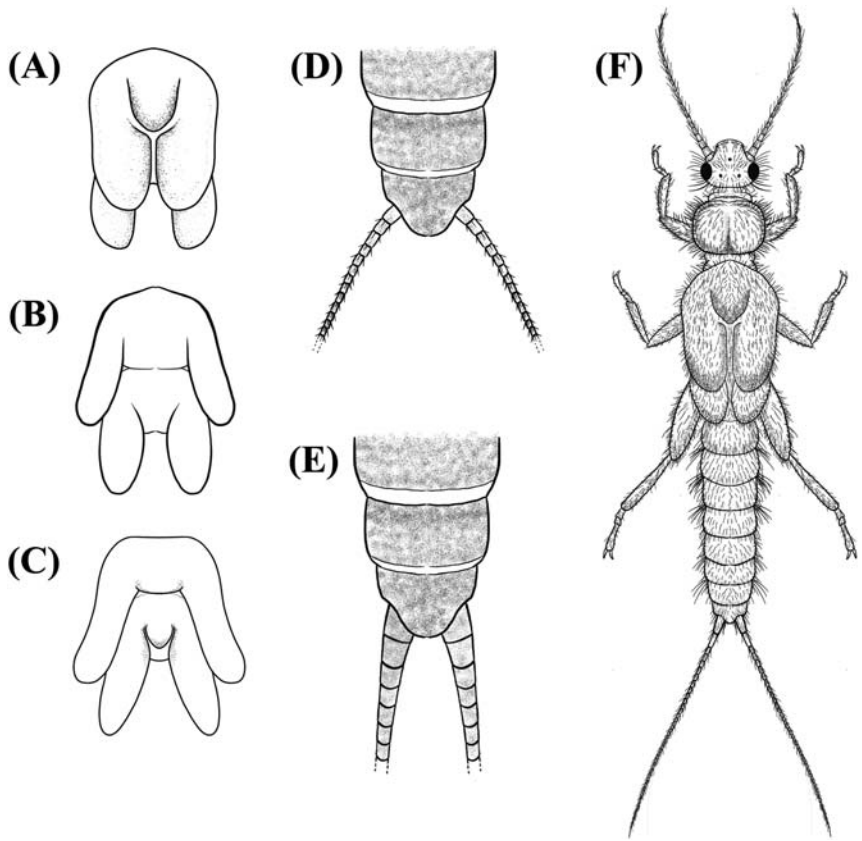


FIGURE 10.17 Wingpad silhouette (not showing hairs when present) of (A) *Capnopsis*; (B) *Capnia/Zwicknia*; (C) *Capnioneura*. Distal part of the abdomen showing the basal part of the cerci (in dorsal view) of (D) *Capnia/Zwicknia*; (E) *Capnioneura*. (F) Habitus of *Capnopsis*.

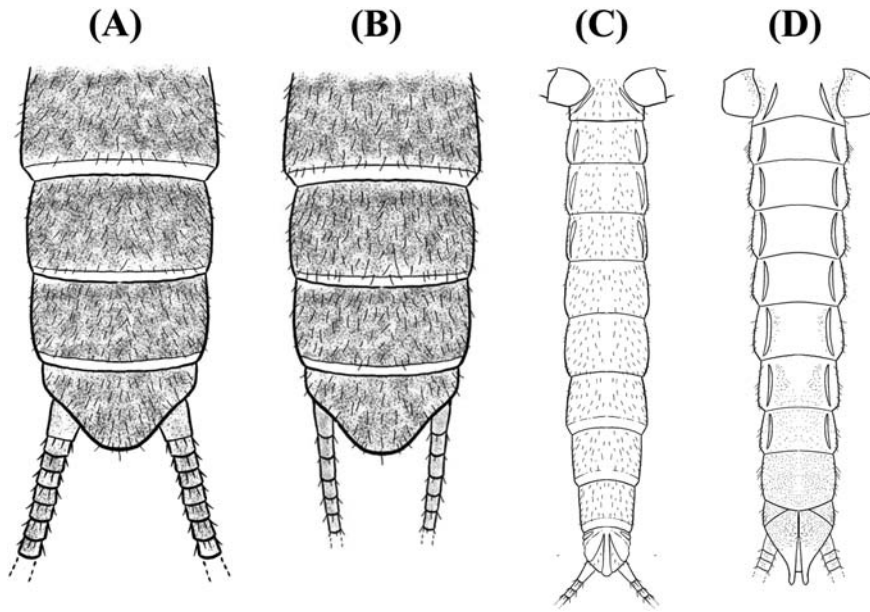


FIGURE 10.18 Distal part of the abdomen (in dorsal view) showing the proximal part of the cerci of (A) *Leuctra*; (B) *Pachyleuctra*. Abdomen (in ventral view) of (C) *Leuctra*; (D) *Tyrrhenoleuctra*. Figures C and D redrawn from *Consiglio (1980)*.

Plecoptera: Leuctridae: Genera

(Three genera and approximately 129 species in the Mediterranean Basin)

- 1 Cercus approximately 1/5 the width of tergite 10 (Fig. 10.18A). Very slender body 2
 1' Cercus slender (thread-like), less than 1/8 the width of tergite 10 (Fig. 10.18B). Relatively stout body
 *Pachyleuctra*
 2(1) Abdominal segments 1 to 4 divided into tergite and sternite by a membranous pleura (Fig. 10.18C) *Leuctra*
 2' Abdominal segments 1 to 8 divided into tergite and sternite by a membranous pleura (Fig. 10.18D)
 *Tyrrhenoleuctra*

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