

margins of the sternal plates, the functions of these muscles as efficient depressors is limited (Fig. 34). This may be the reason why the muscles running obliquely in the tergal plates become the depressors in these segments (Fig. 35).

Type of abdominal structure

The present study indicates 3 types of apomorphic states associated with the formation of an additional petiole or petioles in the anterior abdominal segments (Figs. 31 to 33). The first type of the apomorphic states (Fig. 31) is found in Tiphidae, Mutillidae and Scoliidae, where the presclerites of the third segment are developed to form a projection fitting tightly into the posterior foramen of the second abdominal segment. The pretergum of the second abdominal segment expands laterally, embracing the presternum. The second type of the apomorphic states (Fig. 32) is represented by Vespidae and Formicidae, where some accessories are added to the first type. These aculeates have more laterally expanded pretergum of the third segment than that in the first type, with the development of lateral incisions or depressions on the posterior foramen of the second segment. The third type of the apomorphic states (Fig. 33) is found in certain members of Formicidae, such as Myrmicinae, Cerapachyinae and the ponerine tribe Proceratiini, where a different type of articulatory structures is derived from the second type. The presternum of the third segment in these formicids is bulged ventrally to form a ball-like projection with the pretergum and the posterior foramen of the second segment lost lateral incisions or depressions. In addition, the third type of apomorphic states occur on the third and fourth segments in the ponerine tribes Amblyoponini and Ectatommini, Cerapachyinae, Pseudomyrmecinae, Myrmeciinae and Myrmicinae.

In all these types of the apomorphic states, the pretergum and presternum are connected immovably at their lateral junctures and the musculature shows that certain tergal muscles are modified to act as the levators and depressors of the abdomen from as the retractors and pronators (Fig. 35).

Phylogenetic relationships among Vespidae, Scoliidae and Formicidae

Whether Vespidae is the sister group of Formicidae, or of Scoliidae is a major problem for the phylogeny of Aculeata (Cf., RASNITSYN, 1988; BROTHERS & CARPENTER, 1993). In the most recent study, BROTHERS & CARPENTER (1993) supported the relationship of (Formicidae + (Vespidae + Scoliidae)). By the testing with the additional character proposed in the present study, their hypothesis requires reversal evolution in Scoliidae from the second type to the first type of the states in an additional petiole, or independent occurrence of the second type of the apomorphic state both in Formicidae and Vespidae.

A close examination of the analysis of BROTHERS & CARPENTER (1993) shows that their justifications are not so strong. Firstly, among their 20