

**Biodiversity of the two-pronged bristletails (Diplura)
in Western Australia
as revealed from recent mining projects**



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Introduction

The two-pronged bristletails (Diplura) are an ancient group of six-legged soil arthropods that are currently considered as the insects closest relatives (e.g., Koch 1997, 2000). They presumably already evolved in the Early Devonian (about 400 million years ago) and today show a worldwide distribution in preferably tropical and subtropical regions. Members of this group are usually minute, blind, mostly unpigmented and soft-bodied. The main subgroups are distinguished by the shape of their terminal appendages, which are either short and equipped with a terminal spinning gland (Fig. 1: Projapygoidea), or filiform and antenna-like (Campodeoidea), or pincer-shaped as in earwigs (Japygoidea). Body size usually ranges between 3-10 mm except for some predaceous japygoids like the South American Dinjapygidae, the Australian Heterojapygidae, or the Chinese Gigasjapyginae, which show body lengths up to 6 cm. Among the nearly 980 species described thus far, only 11 species are known from Western Australia (last surveyed by Houston 1994). The actual number of species in Western Australia is supposed to be much higher as their taxonomic knowledge is largely restricted to the Southwest coastal zone, whereas all remaining regions in Western Australia remained poorly sampled until recently.

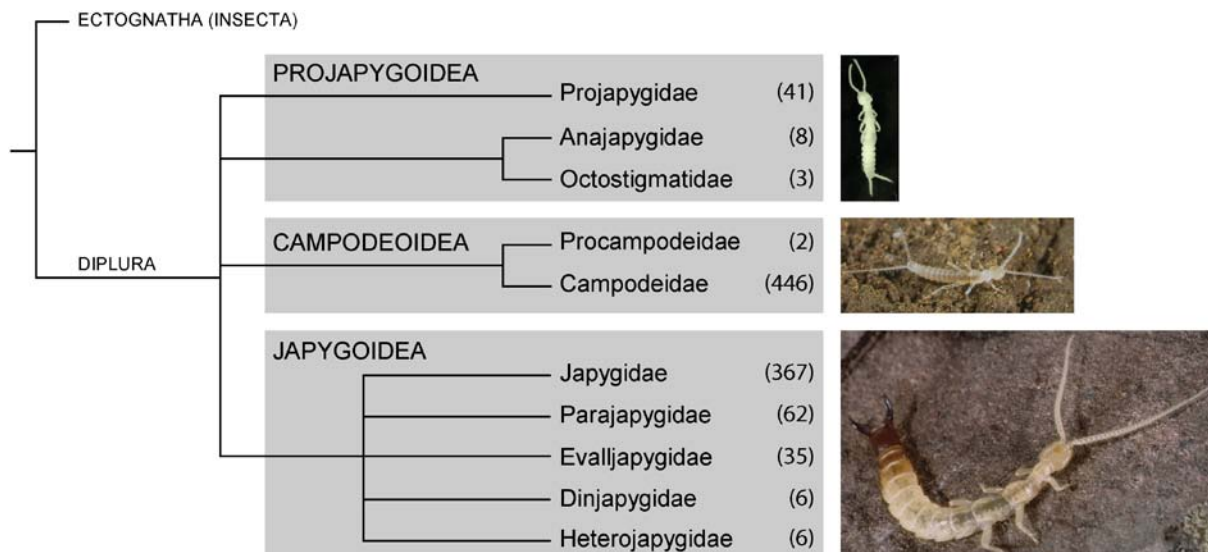


Fig. 1 Classification of the Diplura (modified from Koch 2009). The interrelationships among the ten currently recognized families still remain largely unclear. Numbers in brackets refer to the number of species described thus far. The habitus of representative exemplars are shown in the photographs [from top to bottom: *Symphylurus* sp. (original), *Campodea* sp. (from Günther et al, 2004), Japygidae gen. sp. (from Hans Henderickx)]. The size of the photographs reflects the relative difference in body size.

In recent years, environmental impact assessments linked to economic exploration of resources by mining companies revealed an astonishing diversity of subterranean arthropods in arid and semiarid zones that were formerly assumed to be species-poor (see Austin et al. 2008). The discovery of a japygid on the western edge of the Great Victoria Desert by the Consulting Agency *ecologia Environment* was particularly surprising as diplurans are strongly dependent on humid habitats. This and further findings from Pilbara by *BIOTA Environmental Sciences* (Humphreys et al. 2006) indicated that diplurans may form another lineage of subtropical fauna that survived the aridification of formerly forested habitats by invading deeper levels of subterranean environments (Humphreys 2000). The importance of such survivors is reflected in their potential to undergo short-range endemism. For environmental impact assessments, short-range endemics are of particular relevance as they are prone to be “*the most vulnerable components of biodiversity*” in being strongly susceptible to habitat modification (Edward and Harvey 2008). In order to assess the conservation significance of Australian diplurans, the Tropicana Joint Venture and *ecologia Environment* supported a first survey of their biodiversity in Western Australia based on the more recent Diplura collections deposited at the Western Australian Museum. This survey was performed in collaboration with Dr. Mark Harvey during the author’s two-week visit of the Museum in October 2009 and confirmed an outstanding significance of the available samples.

Results

The specimen collected at the western edge of the Great Victoria Desert (cover picture, courtesy of M. Davis, *ecologia*) proved to be a member of the Japygidae. The characteristic arrangement of antennal sensory organs (trichobothria) indicates that the specimen belongs to the genus *Indjapyx*. The chaetotaxy of the trunk, however, does not correspond to any description for species of this genus known thus far; hence, the specimen likely represents a species new to science. The genus *Indjapyx* is yet only known from Madagascar, India, the Indo-Malayan Region, Southeast China, and Pacific Islands. Its existence in Australia was presumed (Houston 1994) but not verified thus far. Main reason for this uncertainty is that “*the Australian japygids are too poorly known to permit a correct generic assignment of all species*” (Condé and Pagés 1991) – a deficiency that persists until today. In order to clarify the distribution of *Indjapyx* species in Western Australia and potential short-range endemism, all recent collections of diplurans at the Western Australian Museum were studied. Main results of this survey are summarized in Table 1 (Appendix) and are outlined below.

JAPYGIDAE

Representatives of the genus *Indjapyx* have also been discovered from various localities in Pilbara, particularly at the Cape Range and the Mesa formations close to Pannawonica. Since some parts of the respective collections were on loan to Jean Pagés (Dijon, France), it could not yet been clarified whether all these representatives belong to the same species. Personal communication with Jean Pagés, however, confirmed the occurrence of *Indjapyx* species in the Pilbara. In the same region, further representatives of the subfamily Japyginae were detected, but their generic status could not be determined; they are probably new to science and indicate that japygids are more diversified in Western Australia than previously assumed.

Additional spectacular findings concern large members (about 2 cm body length) of the subfamily Japygellinae Womersley, 1939, which were discovered in samples from the Kimberleys. Members of this subfamily are easily distinguished from other japygids by their short, stumpy cerci (Fig. 2). Only six species are known worldwide, most of which are restricted to Africa except for the monotypic *Japygianus wheeleri* Silvestri, 1947, which has been found in North Queensland (Australia). The specimens from the Kimberleys correspond in some details to *Japygianus wheeleri*, but they doubtless represent a species new to science.

Among the six described species of the genera *Japyx* and *Notojapyx* known from the Southwest coastal zone, none of them were discovered in any samples from other regions of Western Australia.

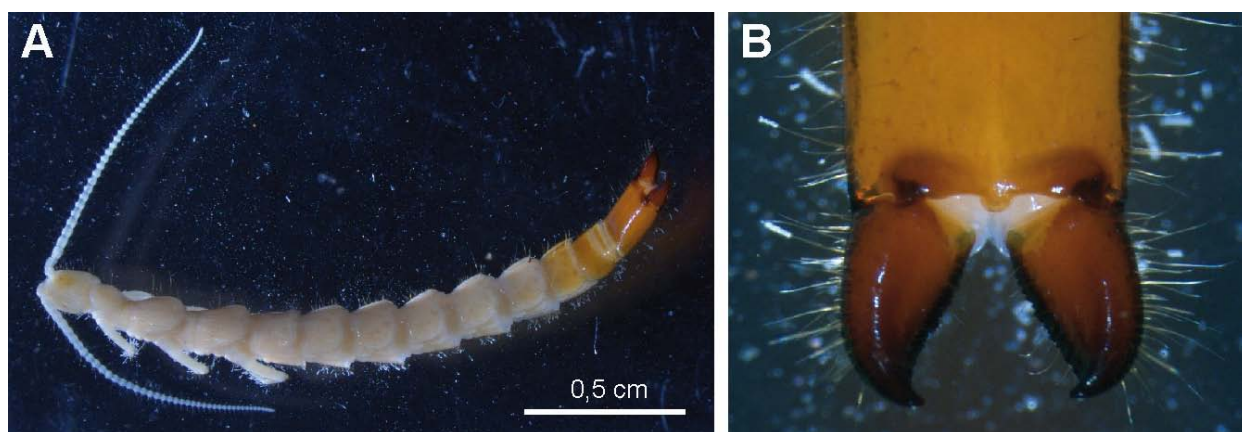


Fig. 2 Micrographs of a new species of the Japygellinae (Japygidae) from the Kimberleys. **A**, adult specimen in side view. **B**, dorsal view of the distinctive pincer-shaped cerci.

PARAJAPYGIDAE

Members of the Parajapygidae are usually minute, hardly exceeding 3-4 mm in body length. They are characterized by the lack of antennal trichobothria and by a distinct arrangement of large exertile vesicles on the abdominal trunk segments II-III. In Western Australia, this family is known from a single species, *Parajapyx swani* Womersley, 1934. Members of this species were identified in samples from the Mesa formations in Northern Pilbara. In samples from this region, however, further *Parajapyx* species were discovered that are probably new to science. Available samples indicate that this genus is a promising new candidate for testing short-range endemism.

HETEROJAPYGIDAE

Species of the genus *Heterojapyx* are only known from Madagascar, Central Asia (Pamir Mountains and Tibet), Australia, and New Zealand. The four described *Heterojapyx* species from Australia occur along the Southeast coastal zone, from South Queensland over New South Wales to Victoria. Specimens of a putatively new species from the Mesa formations in Northern Pilbara (Humphreys et al., 2006) proved to be members of the Japygidae or Parajapygidae, respectively. The Heterojapygidae accordingly still remain unknown from Western Australia.

PROJAPYGIDAE

The Projapygidae are species-rich in Central and South America as well as in Africa, whereas only a few additional species were recorded from Madagascar, Southeast Asia, and Australia. Australian projapygids are only known from a single species, *Symphylurinus swani* Womersley, 1945, from North Queensland. A second, undescribed species was stated by Houston (1994) to occur in Western Australia. New evidence from recent samples of the North-western Mesa formations as well as of Barrow Island confirms the existence of a new *Symphylurinus* species in Western Australia (Fig. 3). Additional specimens from the Cape Range were recently collected by Stefan Eberhard (personal communication). The Western Australian *Symphylurinus* species seem to show a similar distribution pattern as members of the arachnid order Schizomida (Harvey et al. 2008).



Fig. 3 *Symphylurinus* sp. nov. (Projapygidae) from the Cape Range.

CAMPODEIDAE

Among the Australian campodeids known thus far, species of the subgenus *Indocampa* are considered as the only “native” (i.e., autochthonous) representatives (e.g. Condé 1980). This subgenus shows a similar biogeographical distribution as the japygid genus *Indjapyx* in ranging from Madagascar over Sri Lanka, the Indo-Malayan Region, Papua New Guinea, and New Caledonia to Polynesian Islands, but it was also recorded from Australia and Tasmania by a single species each. In samples of campodeids from the Pilbara, the widespread Australian species *Campodea (Indocampa) tillyardii* Silvestri, 1931 was discovered as well as additional representatives of the subgenus *Indocampa* that cannot be assigned to any known species. These new findings contribute to the ongoing discussion of the origin of the Australian Campodeidae. *Indocampa* species may not form a natural group as they proved to be less clearly distinguished from the cosmopolitan subgenus *Campodea* as formerly assumed (e.g., Condé 1980). Instead, a closer relationship to the campodeid genus *Cocytocampa* has been put forth by Condé (e.g., 1990). This view received corroboration from his discovery of the first Australian species of this genus, *Cocytocampa humphreysi* Condé, 1998, in a cave at the Western Australian Cape Range. Another, still undescribed *Cocytocampa* species was recently discovered on the Christmas Island (Humphreys and Eberhard 2001).

Significance of dipluran subterranean biodiversity in Western Australia

Primarily with the long-term view to providing taxonomic descriptions of any new species, this first survey confirmed that the recent samples of Western Australian diplurans are significant in three major aspects:

- (i) Short-range endemism. – The discovery of undescribed species from the Great Victoria Desert and the Pilbara indicates that the families Japygidae, Parajapygidae, and Campodeidae diversified in semiarid and arid regions of Western Australia. This particularly concerns the genera *Indjapyx* and *Parajapyx* as well as the subgenus *Indocampa*, all of which were known to date from just a few “Oriental” species and a single Australian species, if at all. They deserve serious attention in future studies aiming at environmental assessments to clarify whether they are similarly indicative for short-range endemism as hypogean arachnids (Harvey et al. 2008, Edward and Harvey 2008).

- (ii) Origin, evolution and biogeography of the biota of the Indo-Pacific and Australasian regions. – The Western Australian japygids, campodeids, and projapygids show close relation to the Malagasy, Indo-Malayan, and Southeastasian fauna. Present insights on dipluran biodiversity accordingly indicate that they can contribute to more broad-scale biogeographical questions, like Gondwanan distribution patterns. As a group of primitive hexapods with ancient origin, low vagility and restricted habitats, diplurans correspond to primitive arachnids in inhabiting all major landmasses with the exception of Antarctica despite lacking the ability to disperse across oceanic barriers. This qualifies them to test the hypothesis of continental drift as main driving force for a diversification through vicariance, as has recently been demonstrated for arachnids (Boyer et al., 2007).
- (iii) Higher-level phylogeny. – The interrelationships among the major dipluran subgroups presently remain unclear (Fig. 1). This is because of the difficulty to include representatives of those subgroups into phylogenetic studies that seem to represent “evolutionary links” in combining distinctive characters of the most species-rich families Campodeidae and Japygidae. In this regard, the Projapygoidea are most decisive to clarify character evolution in diplurans and to reconstruct their ancestral states, but they are rare and were usually found by accident only. Recent collections indicate that not only projapygids are more widespread in Western Australia than previously assumed, but also members of the species-poor families Octostigmatidae and Procampodeidae (current records of these families, however, still require confirmation). Their sampling in Western Australia opens the possibility to fill an essential gap to unravel the natural history of the insects’ putatively closest relatives and thereby to contribute to persisting questions on the origin and early evolution of insects.

Conclusions and perspective

Since Houston (1994) summarized the poor knowledge of the dipluran fauna to “*raise the awareness of the scientific community to the need for a comprehensive taxonomic revision of the Australian Diplura*” (p. 139), this survey can be considered as the first progress. Present insights underline both their significance for major scientific questions in arthropod phylogeny as well as their meaning for environmental impact assessments. Further steps towards Houston’s intention will be the description of the new species discovered thus far to make them available to the science community. This will facilitate present attempts to initiate long-term collaboration on

the dipluran fauna in Australia based on fundings of the Australian Government and the German Research Foundation.

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APPENDIX

Table 1 Identification of recent dipluran samples at the Western Australian Museum

Family	Identification	Individuals	Sample	Locality
JAPYGIDAE				
Indjapyginae	<i>Indjapyx</i> sp.	3 adults, 6 juveniles	BES11299, BES 11281	Pilbara, Cape Range: Learmonth Limestone
	<i>Indjapyx</i> sp.	about 20	Aquila-project (BIOTA)	Pilbara: Pannawonica
	<i>Indjapyx</i> sp.	1	Tropicana Troglo- fauna (ECOLOGIA) BES14722	Western edge of the Great Victoria Desert
Japyginae	gen. sp.	2	Mesa-project (BIOTA)	Pilbara, Pannawonica: Mesa K, Mesa F
	gen. sp.	1	Nambung National Park (BES12264)	South Hill River Caves
Japygellinae	? <i>Japygianus</i> sp.	6 adults, 6 juveniles	Kimberley Pears Tunnel (BES 5446, 5452, 6225, 6106, 6226)	Kimberleys: Old Napier Downs Cave
PARAJAPYGIDAE				
	<i>Parajapyx swani</i> Womersley, 1934	1	Mesa-project (BIOTA)	Pilbara, Pannawonica: Mesa C
	<i>Parajapyx</i> sp.	1	Mesa-project (BIOTA)	Pilbara, Pannawonica: Mesa B
	<i>Parajapyx</i> sp.	1	Murrays Hill (ECOLOGIA)	Pilbara, Pannawonica, Mulga Downs Station
PROJAPYGIDAE				
	<i>Symphylurinus</i> sp.	2	Mesa-project (BIOTA)	Pilbara, Pannawonica: Mesa A
	<i>Symphylurinus</i> sp.	1	Barrow Island Troglofauna (BIOTA)	Barrow Island
CAMPODEIDAE				
Campodeinae	<i>Campodea (Indocampa)</i> <i>tillyardii</i> Silvestri, 1931	1	BES 7395	Pilbara: Cape Range
	<i>C. (Indocampa)</i> sp.	3	Mesa-project (BIOTA)	Pilbara: Cape Range