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DEVELOPMENT AND MORPHOLOGY OF *UNDULORIBATES UNDULATUS* (BERLESE, 1914) (ACARI: ORIBATIDA) AND SOME REMARKS ON THE UNDULORIBATIDAE

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Unduloribates undulatus, a moss-dwelling species living in alpine habitats of the European Alps, the Sudeten mountain range (Giant Mountains), and the Carpathians, is redescribed in detail and information on the ontogenetic development is given. The species-specific characteristics are ten pairs of long and spiniform notogastral setae, long and spinose interlamellar setae, a slender, longish lenticulus and the juveniles show a plicate integument, a lateral carinate opisthosomal dorsum, uniform short spiniform notogastral setae, keel-like lamellae and femoral porose areas. The comparison with *U. brevisetosus*, *U. dianae*, *U. hebes* and *U. medusa* showed clear separation of all species. *Koreoribates,* the second genus of Unduloribatidae, is a junior synonym of *Unduloribates*, as the described characters of its only species, *K. foliatus*, well fit the known range of traits in the latter genus.

Keywords: morphology, development, Phenopelopoidea, *Koreoribates*, taxonomy

INTRODUCTION

BALOGH (1943) introduced the genus *Unduloribates* with the type species *Tectoribates undulatus* which was described in 1914 by BERLESE as *Sphaerozetes (Tectoribates) undulatus*. Later, BALOGH (1961) assigned this genus to the family Oribatellidae, but KUNST (1971) refused this classification and proposed the new family of Unduloribatidae. PIFFL (1972) introduced the same family name without being aware of the KUNST publication and he related this taxon to the pycnonotic apheredermata (GRANDJEAN 1953). NORTON and BEHAN-PELLETIER (1986) included the Unduloribatidae as the second family with Phenopelopidae in the Phenopelopoidea. Furthermore they confirmed the Phenopelopoidea as "Circumdehiscentiae with wrinkled nymphs" (GRANDJEAN 1953). Up to the present there are five species of the genus *Unduloribates* known: *U. undulatus* (BERLESE, 1914), *U. dianae* BEHAN-PELLETIER et WALTER, 2009, *U. hebes* AOKI, 1965, *U. medusa* PIFFL, 1972 and *U. brevisetosus* NÜBEL-REIDELBACH et WOAS, 1992. This genus shows a Holarctic distribution with a predominantly occurrence in high montane and alpine habitats (CHOI 1994). All of these species are more or less well described except for the type species *U. undulatus*. BERLESE (1914) wrote only a

short note about the morphology and depicted the animal incompletely. BALOGH (1943) criticized this description but he also gave only incomplete information about this species and showed a picture with only a few more details. HAMMER (1977) provided a dorsal and ventral drawing of *U. undulatus* found in Pakistan, but she reported that these specimens show some deviations from BERLESE's original description. WEIGMANN (2006) was the only one who presented a helpful dorsal depiction as well as general information of *U. undulatus* in his identification key. Data on the juvenile stages of any species within the genus *Unduloribates* is only available for *U. medusa* (PIFFL 1972) and *U. dianae* (BEHAN-PELLETIER & WALTER 2009). Therefore, this paper provides a detailed analysis of *U. undulatus* and furthermore the first morphological description of the juveniles of this species is given.

MATERIALS AND METHODS

Specimens were collected from mosses on rocks in high alpine areas of the Eastern Alps in Austria. Sample sites: (1) national park "Gesäuse", Großer Buchstein, 1963 m, N47°36.8' E14°35.8', 23.07.2007; (2) national park "Hohe Tauern" (massif Glocknergruppe), Brennkogel, 2950 m, N47°05.8' E12°49.1', 10.9.2008; Elisabethfelsen, 2140 m, N47°03.9' E12°45.3' 11.9.2008; Knappenstube, 2490 m, N47°05.2' E12°50.7', 12.9.2008.

For breeding experiments adults and nymphs were put into polystyrol-boxes supplied with plaster of Paris and were fed with coccal green algae. Nymphs collected in the same samples as the adults could be clearly assigned to *U. undulatus* as some tritonymphs in culture were pharate, with the adult visible within their bodies. From the few laid eggs only one larva was obtained.

The specimens were embedded in lactic acid for temporary slides and for permanent slides in Berlese mountant. Observations and drawings were performed with a differential interference contrast microscope (Olympus BH-2). The SEM-micrographs were made at the Research Institute for Electron Microscopy and Fine Structure Research, Graz, University of Technology, with a Zeiss Leo Gemini DSM 982. For the attempt to remove cerotegument from the cuticle some specimens were put into a 15% NaOCl (sodium-hypochlorite) solution for 1 hour.

RESULTS

Redescription of Unduloribates undulatus *adult*

Diagnosis. Average length 620 µm, average body width 389 µm. Colour dark brown. Cerotegument with small granules crowded together forming larger dark polygonal spots. Large and broad lamellae. Long spinose interlamellar setae. Sensillus long, clavate and serrate. Ten pairs of long, thin and acuminate notogastral setae. Large tutorium. Immovable triangular pteromorphs. Slender, longish lenticulus. All antiaxial setae *l* on genua and tibiae of legs broadened and serrate. All femora, tarsi as well as trochanters III and IV with porose areas.

Morphology

Body length (N = 16) 583–671 μm. Body width (N = 16) 366–409 μm.

Integument – Cuticle puncticulate, slightly colliculate. Three different types of cerotegument: i) Thick cerotegumental layer, reflecting colliculate pattern of cuticle on notogaster and in anogenital region (Figs 1a, c, d); this layer seems to be covered by a extremely thin pellicle (Fig. 3b) which is destroyed at least partially by NaOCl (Figs 1c, d). ii) Individually differently developed coarse birefringent cerotegument forming a more or less amorphous layer to a roughly reticulate pattern in the lateral and posterior periphery of the notogaster (Fig. 1b); iii) Finely structured cerotegument consisting of small tubercles carried by an basal layer covers all depressions, deepenings and protected areas of the body (e.g. bothridium, acetabula etc.) (Figs 2c & 3c).

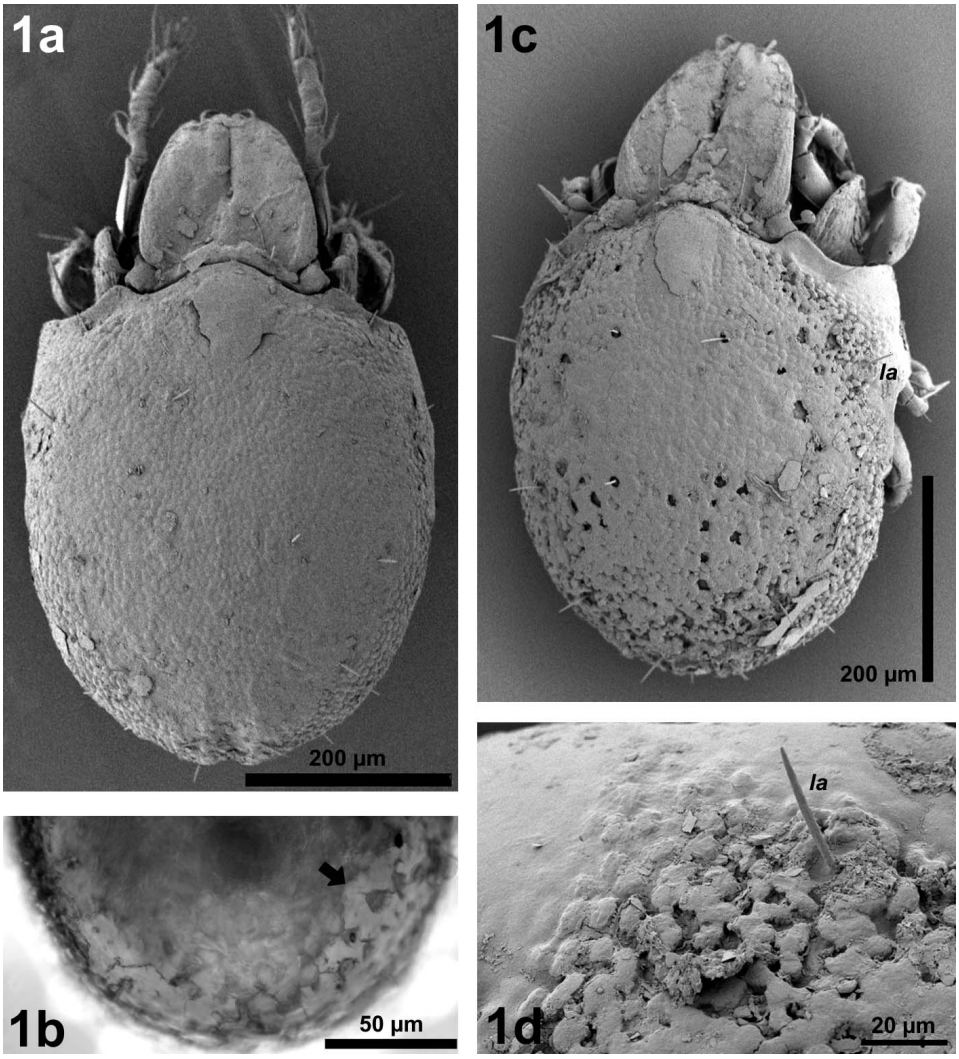
Prodorsum (Figs 1a, 2a, b, 4a, c, 5a) – Sensillus clavate and finely barbed. Bothridia large cylindrical projections with a posterior lateral ridge running ventrally; paraxial border of bothridium anteriorly with cone-like protuberance. Interlamellar setae (*in*) long, thin and spinose inserted on narrow triangular area between lamellae (Fig. 2b). Exobothridial setae (*ex*) long, directed rostrad. Strongly protruding lamellae covering rostrum and rostral setae (*ro*) completely (Figs 2a, 4c, 5a). Lamellae slightly transparent with longitudinal striated structure with notch at base of lamellar seta. Lamellar setae (*le*) long, slightly broadened, barbed and strongly bent ventrally. Lamellae adjacent connected by short concave structure. Well developed triangular tutorium (Tu) with a sharp detached "dens tutorius". Rostral setae (*ro*) slightly barbed inserting on large apophysis (Figs 4c, 5a).

Notogaster (Figs 1a, c, 2a, 4a, c) – Lenticulus narrow and longish (in transmitted light), anterior end vague, posterior end curved and distinct, lateral borders slightly convex. Pteromorphs without hinge, triangular with rounded ventrally bent tips (Figs 2a, 4c). Pteromorphs slightly transparent and striated in transmitted light. Ten pairs of long and thin notogastral setae: c_2, *la*, *lp*, *lm*, h_1-h_3, all of approximately the same length, setae ps_1-ps_3 a bit shorter. Five pairs of lyrifissures present: *ia*, *im*, *ih*, *ips* and *ip*; *ia* hidden beneath pteromorph close to position of seta c_2 and lyrifissure *im* located anterior to seta h_3. Lyrifissure *ips* next to seta h_1, *ip* and *ih* positioned next to each other anteriorly seta ps_3; these lyrifissures are difficult to detect because of the strongly developed cerotegument. Orifice of opisthonotal glands situated closely anterior to seta h_3. No porose areas or saccules representing octotaxic system observable on notogaster.

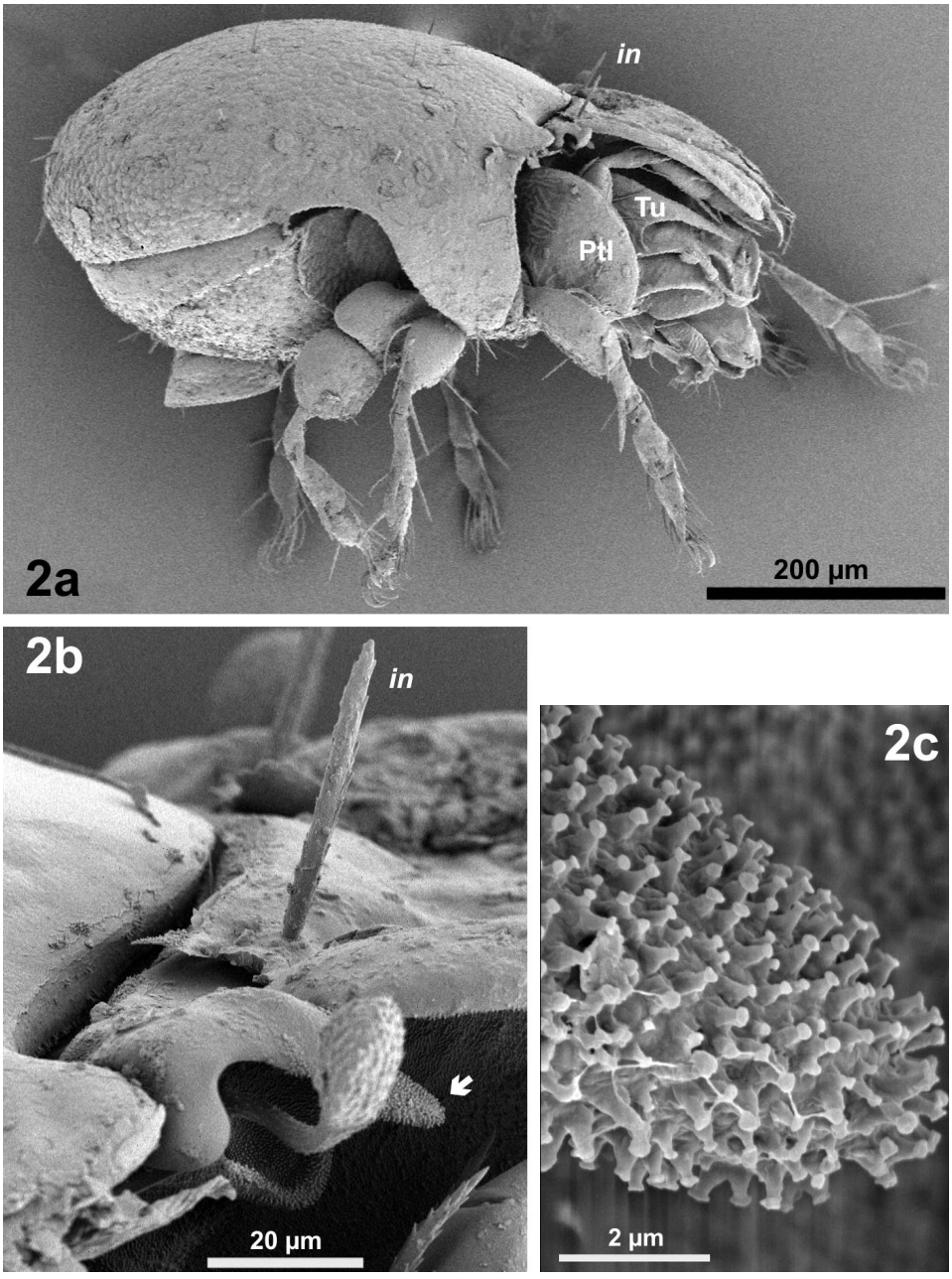
Subcapitulum and camerostome (Figs 5b, 6) – Cuticle smooth. Border of camerostome with a paired incision on level of rutellae. Strong cuticular rib shaped like a trident on anterior border of mentum (Fig. 5b). Paired setae *h* long, slightly spinose. Rutellum with four teeth, distal one largest, the two proximal ones inconspicuous. Paired setae *a* and *m* long, thin and slightly barbed. Adoral setae or_1 and or_2 inserting very close, robust and spinose, about the same length as setae *m*. Pedipalp pentamerous, chaetome without solenidion 0–2–1–3–9, solenidion ω inclined attached to eupathidium *acm* only distally to form so called "incomplete corne double". Setae on femur, genu and lateral setae of tibia serrate. Axillary saccule opens paraxial to insertion of pedipalp.

Ventral region of idiosoma (Figs 3a, 4b, c) – At the dorsal margin of ventral plate in the podosomal region humerosejugal porose area (Ah) is hidden under the pteromorph. Pedotectum I rugose, large and shield-shaped, covering acetabulum I completely in lateral aspect (Fig. 4c). Pedotectum II small, in ventral view rectangular, in lateral view drop-shaped. Custodium and discidium fused (length approximately 15 μm). Long concave circumpedal carina reaching circumgastric scissure posterior acetabulum IV. Epimeral setation (I–IV): 3–1–3–2. Coxisternal ridges of epimeron II medially connected by a longitudinal ridge. Epimeron III and IV laterally fused; anterior to genital opening concave ridge framing a deepening. Genital setation of 9 pairs arranged in a longitudinal line near medial border of plate with few setae slightly laterally located. Genital plates rounded and anteriorly broadened. Genital opening surrounded by thicker and therefore darker cuticle. One pair of

short spiniform aggenital setae *ag*. Three pairs of adanal setae, seta ad_1 longest. Lyrifissure *iad* flanking anterior part of anal orifice. Two pairs of short and spiniform anal setae. Anal valves with rounded borders posteriorly broadened. Preanal organ like a slender chalice, posterior part with two spherical projections.

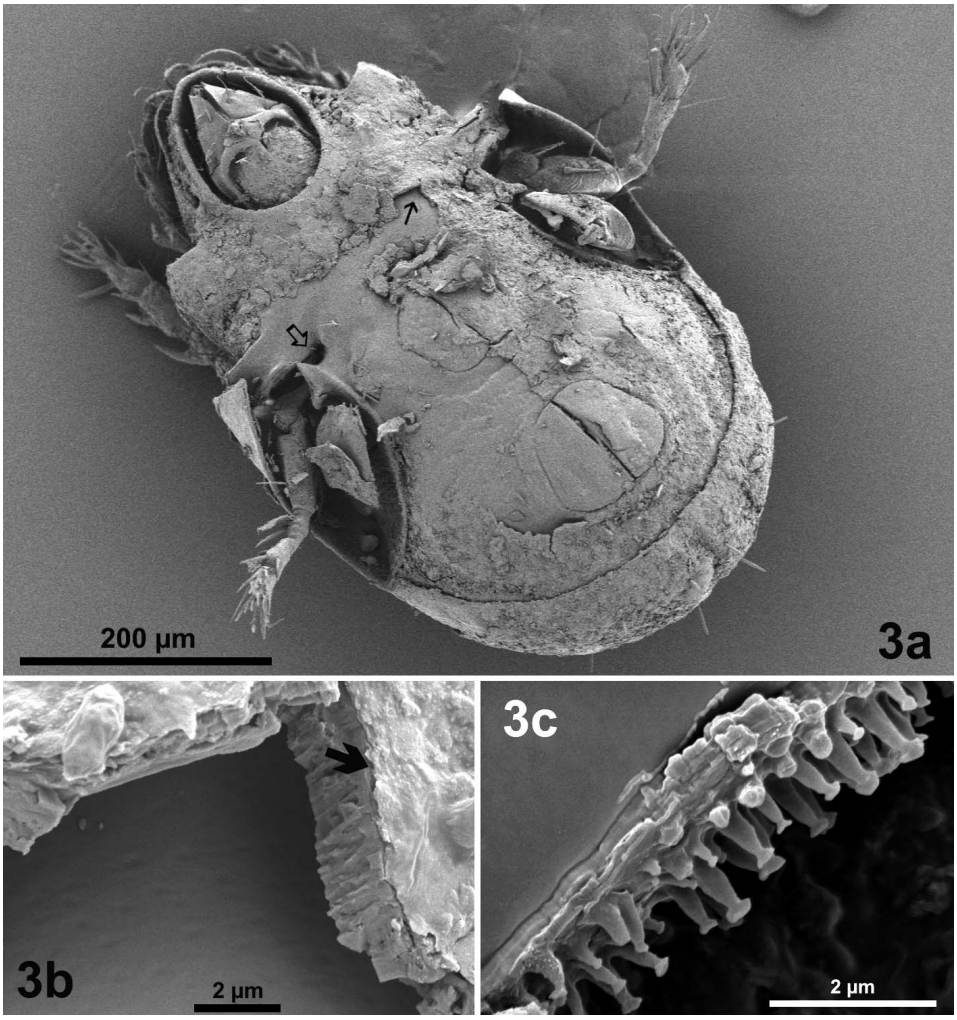


Figs 1a-d. *Unduloribates undulatus*, adult, dorsal aspect (a, c, d SEM-micrographs, b interference contrast micrograph): a = colliculate pattern of notogastral cerotegument type 1, b = posterior part of notogaster with blocky, almost reticulate (arrow), birefringent layer of cerotegument type 2, c = specimen treated with NaOCl, cerotegument type 2 slightly corroded, d = detail to Fig. 1c, area surrounding notogastral seta *la*

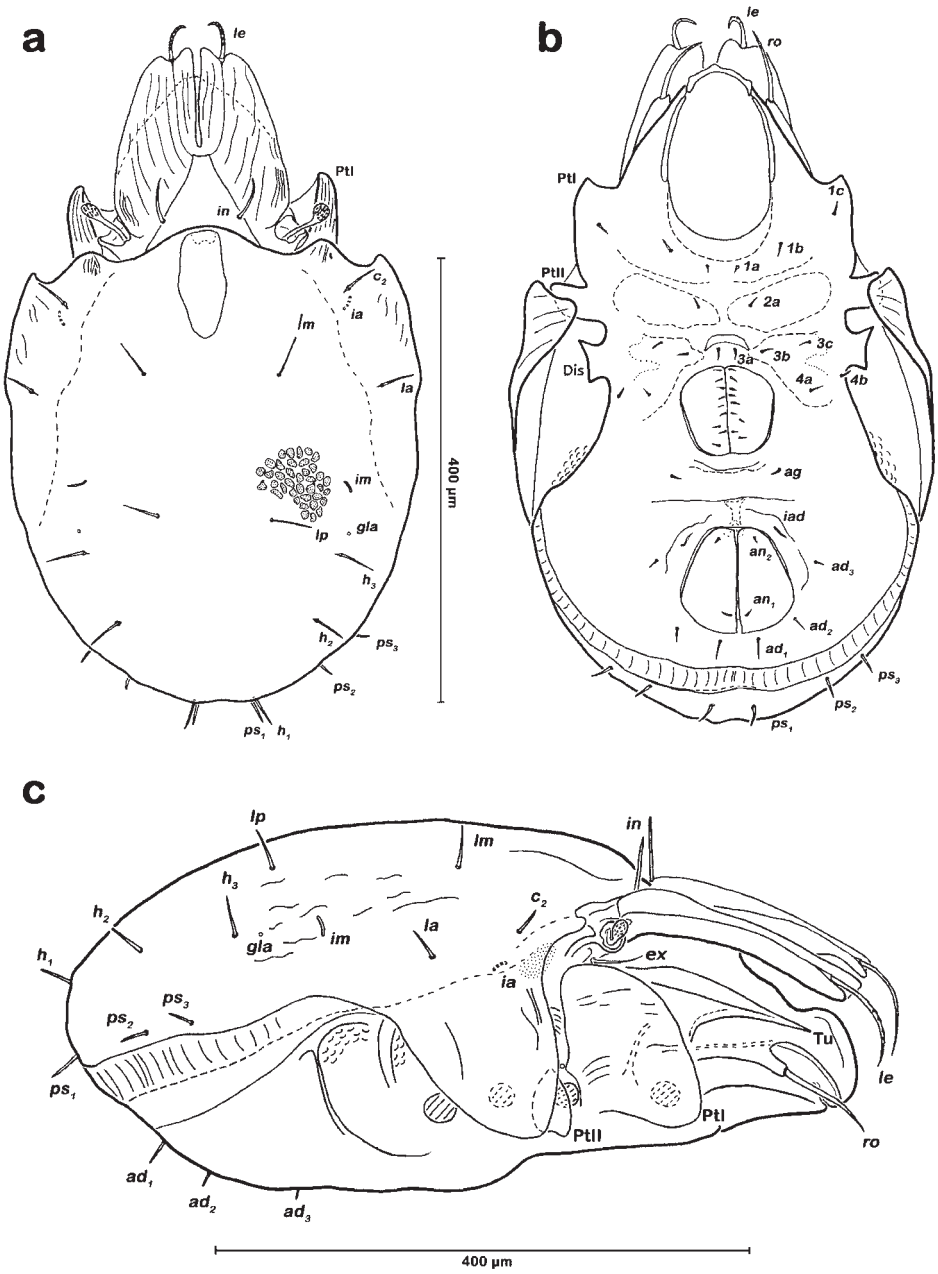


Figs 2a-c. *Unduloribates undulatus*, adult, lateral aspect, SEM-micrographs (*in* interlamellar seta, Tu tutorium, PtI pedotectum I): a = overview, leg 1 partially hidden by PtI and lamella, b = bothridium and sensillus, arrow indicates cone-like protuberance of paraxial border, c = detail of Fig. 2b (arrow), finely structured cerotegument type 3

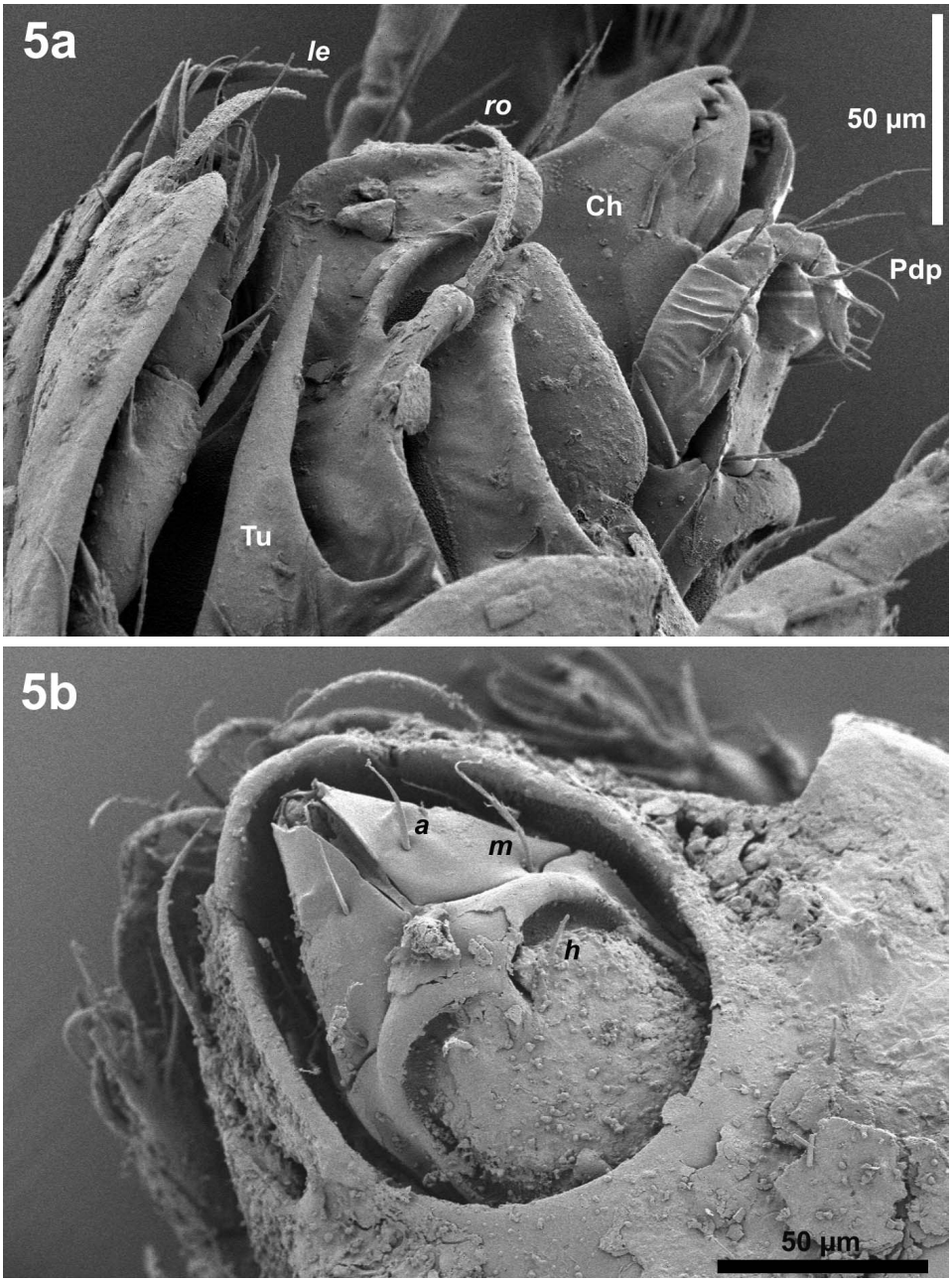
Legs (Figs 7a-d) – Tridactyl, heterodactyl, lateral claws dorsally slightly dentate. Cuticle smooth. All setae from trochanter to tibia serrate, antiaxial lateral setae of genu and tibia extremely broadened. Ventral and lateral setae on tarsi slightly serrate, seta *ft''* on tarsus II and III very robust and broad. On tibia I solenidia φ_1 and φ_2 inserting on small elevation. Large porose areas located on paraxial dorsolateral side of femur I-IV as well as on trochanter III and IV. Porose area of femur II exceptionally concave. Proximal ventral part of all tarsi also with small porose areas. Leg chaetome (excluding solenidia): I (1–5–3–4–18), II (1–5–3–4–15), III (2–4–1–3–15), IV (1–2–2–3–12). Solenidia: I (1–2–2), II (1–1–2), III (1–1–0), IV (0–1–0).



Figs 3a-c. *Unduloribates undulatus*, adult, ventral aspect: a = overview, cerotegument partially detached, b = detail of detaching cerotegument in epimeral region (slender arrow in Fig. 3a), note the thin pellicle covering the cerotegument (bold arrow), c = cerotegument type 3 near acetabulum III (bold arrow in Fig. 3a).



Figs 4a-c. *Unduloribates undulatus*, adult: a = dorsal aspect, b = ventral view, c = lateral aspect. Legs and subcapitulum removed



Figs 5a-b. *Unduloribates undulatus*, adult SEM-micrographs: a = rostrum and mouthparts in lateral view, b = ventral aspect, camerostome and subcapitulum

Juvenile morphology – common features

Integument moderately plicate. Opisthosoma apheredermous. Color yellowish white to light brown. Rostral setae (*ro*) robust, thick and spinose, inserting on small humps on anterior edge of rostrum. With pair of longish narrow longitudinal and parallel keels bearing, solid and spinose lamellar setae (*le*), distal end of setae mostly intersecting. A pair of short interlamellar setae (*in*), located between bothridia. A pair of short capitate and barbed sensilli, border of bothridium projecting and laterally opened. A pair of very short, spiniform exobothridial setae (*ex*) laterally next to each bothridium. Transversal band like porose area posterior interlamellar setae in the dorsosejugal region. A pair of porose areas in the lateral region of prodorsum dorsally of insertion of leg I. Gastronotic region mainly plicated transversally, two strong longitudinal folds forming carinate lateral borders of opisthosomal dorsum. No humeral organ. Notogastral setae short and spiniform. A pair of long spiniform setae (*h*) on mentum. Paired setae (*a*) and (*m*) also long and spiniform. Rutella with three teeth, distal one largest triangular and pointed. Pedipalp pentamerous, chaetome 0–2–1–3–9, solenidion ω attached distally to eupathidium *acm* (Fig. 8). Pouch like axillary sacculus at base of pedipalp. Mentotectum divided medially. Epimeral setae short and spiniform. Posterior part of ventral opisthosomal region strongly plicated. Sac-like inconspicuous opisthonotal glands (gla). Large porose areas surrounding orifice of opisthonotal gland. Legs monodactyl, lateral setae of all limbs robust, broadened and serrate, solenidion φ_1 on tibia I inserting on strongly projecting apophysis; large porose areas on ventral paraxial side of each femur. No setae coupled to solenidia on tibiae and femora in any stage. Developmental formulas in Table 1.

Eggs – The exochorion of the egg of *U. undulatus* consists of a thick layer showing irregular reticular furrows (Fig. 9a). Time from egg-laying to eclosion of one egg found in culture was 42 days.

Larva (N = 1) – Body length 231 μm.

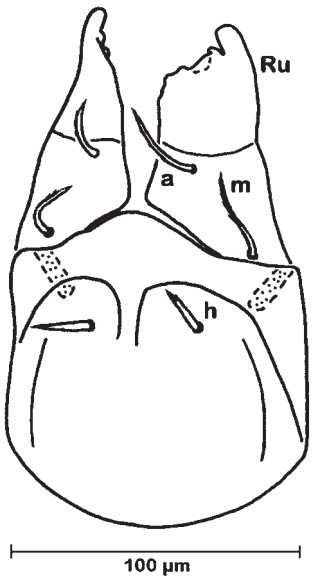


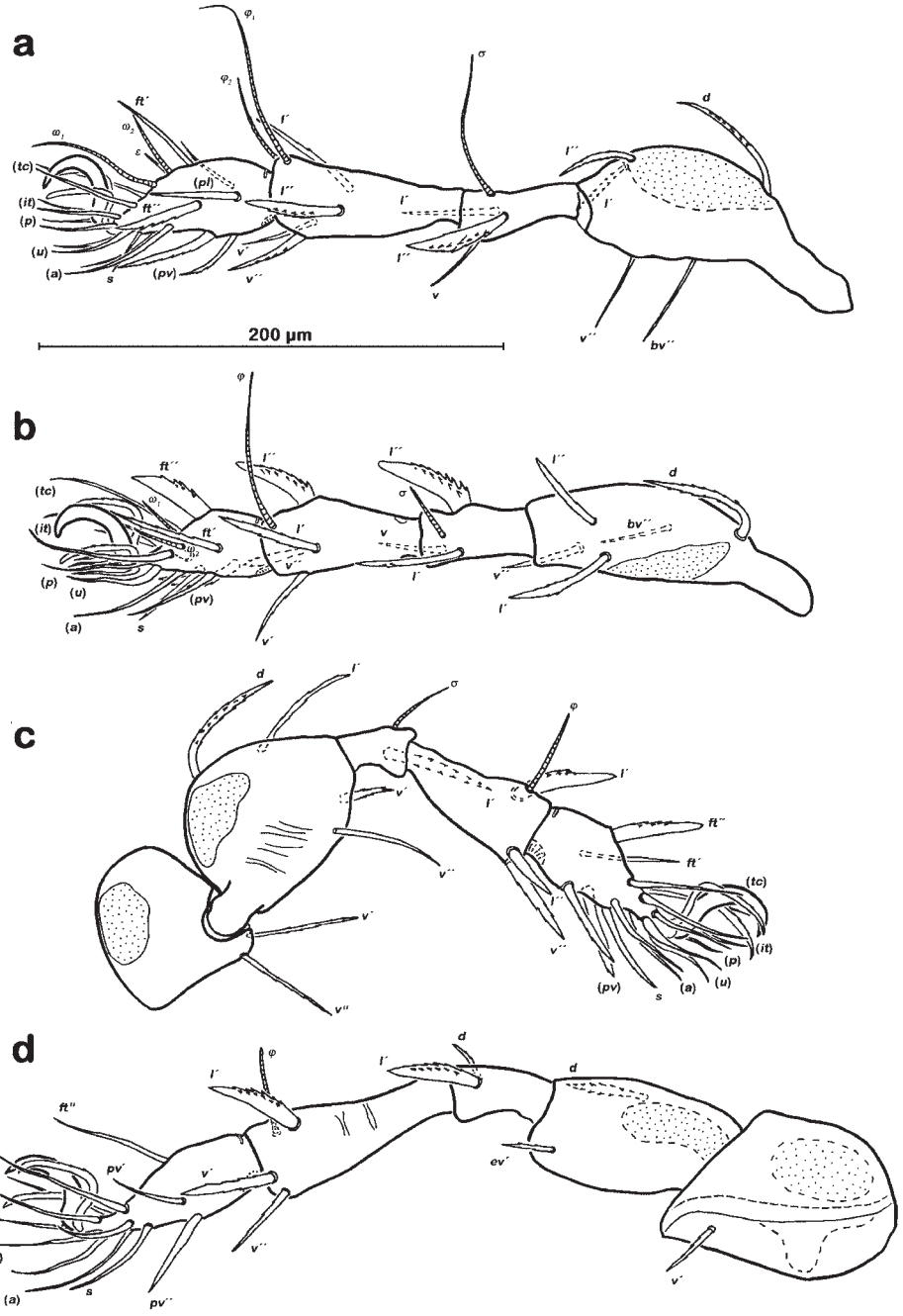
Fig. 6. *Unduloribates undulatus*, adult, subcapitulum ventral view

Twelve pairs of gastronotic setae: c_{1-3}, *da*, *la*, *dm*, *lm*, *dp*, *lp*, h_{1-3}. Seta h_3 vestigial, lateral to median part of anal opening (Fig. 10); seta h_2 robust, largest of all gastronotic setae, next to posterior part of anal opening. Cupula *ia* lateral on a level with dorsosejugal scissure, *im* located between setae *lm* and *lp*. Cupula *ih* flanking anterior border of anal opening, *ip* lateral between setae h_1 and h_2. Epimeral setation 3–1–2 (seta 1c represented by the scale covering Claparede's organ).

Protonymph (N = 2) – Body length 304–322 μm, average 313 μm.

Fifteen pairs of gastronotic setae, seta ps_{1-3} arranged in a longitudinal row next to anal opening. Epimeral setation 3–1–2–1, seta *1c* on lateral border of epimeron I, seta *4a* next to posterior margin of epimeron IV (Fig. 11a). One pair of short spiniform genital setae in center of each genital valve. Cupula *ih* located laterally and *ips* in analogous position of *ih* in larva. Short solenidion ω_2 added posterior to ω_1 on tarsus I (Figs 12a-d).

Deutonymph (N = 4) – Body length 384–484 μm, average 445 μm.



Figs 7a-d. *Unduloribates undulatus*, adult: a = left leg I antiaxial view, b = right leg II paraxial view, c = right leg III paraxial view, d = right leg IV antiaxial view

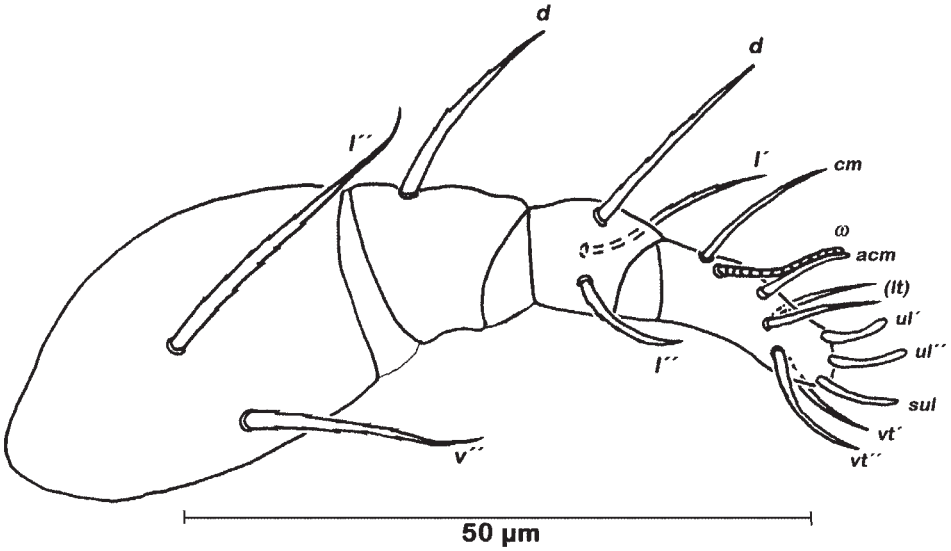
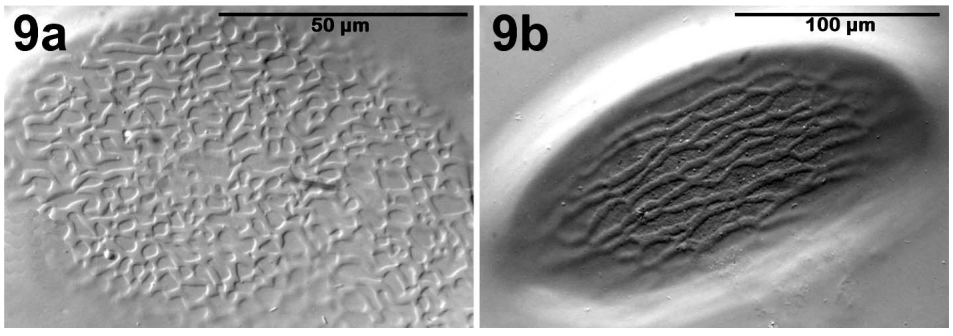


Fig. 8. *Unduloribates undulatus*, protonymph: right pedipalp antiaxial view

Fifteen pairs of gastronotic setae (Fig. 11b). Epimeral setation 3–1–3–1, paired setae *3c* added in median position. Four pairs of short spiniform genital setae arranged in row. One pair of short spiniform aggenital setae (ag_1) posterior to genital orifice. Three pairs of short adanal setae, ad_{2-3} flanking anal valves, ad_1 slightly posterior to anal opening. Cupula *ips* located laterally, *iad* flanking now anterior part of anal aperture. Short solenidion φ_2 laterally on distal apophysis of tibia I. Solenidion ω_2 posterior to ω_1 on tarsus II. On tibia IV short solenidion φ added in dorsal position.

Tritonymph (N = 6) – Body length 608–702 µm, average 644 µm.

Fifteen pairs of gastronotic setae (Figs 11c, d). Epimeral setation 3–1–3–2, seta *4b* lateral to seta *4a*. Seven pairs of genital setae. Two pairs of short anal setae (an_{1-2}) on anal plates.



Figs 9a–b. Interference contrast micrographs of egg exochorion structure: a = *Unduloribates undulatus*, b = *Eupelops* sp.

Table 1. Developmental characteristics of *U. undulatus*. Leg chaetome from trochanter to tarsus (excluding solenidia).

	Larva	Protonymph	Deutonymph	Tritonymph	Adult
Notogastral setae	12	15	15	15	10
Epimeral setation	3–1–2	3–1–2–1	3–1–3–1	3–1–3–2	3–1–3–2
Genital setae	0	1	4	7	9
Aggenital setae	0	0	1	1	1
Adanal setae	0	0	3	3	3
Anal setae	0	0	0	2	2
Chaetome leg I	0–2–2–3–16	0–3–2–3–16	0–4–3–3–16	1–4–3–4–18	1–5–3–4–18
Chaetome leg II	0–2–2–2–13	0–3–2–2–13	0–4–3–3–13	1–4–3–4–15	1–5–3–4–15
Chaetome leg III	0–2–1–1–13	0–2–1–1–13	1–3–1–2–13	2–3–1–3–15	2–3–1–3–15
Chaetome leg IV	–	0–0–0–0–7	0–2–2–1–12	1–2–2–3–12	1–2–2–3–12
Solenidia leg I	1–1–1	1–1–2	1–2–2	1–2–2	1–2–2
Solenidia leg II	1–1–1	1–1–1	1–1–2	1–1–2	1–1–2
Solenidia leg III	1–1–0	1–1–0	1–1–0	1–1–0	1–1–0
Solenidia leg IV	–	0–0–0	0–1–0	0–1–0	0–1–0

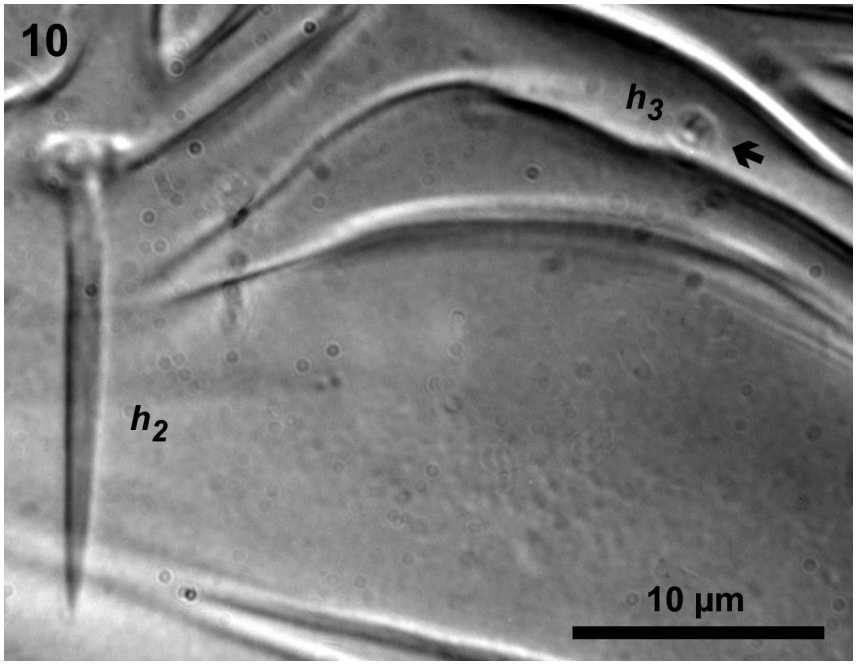
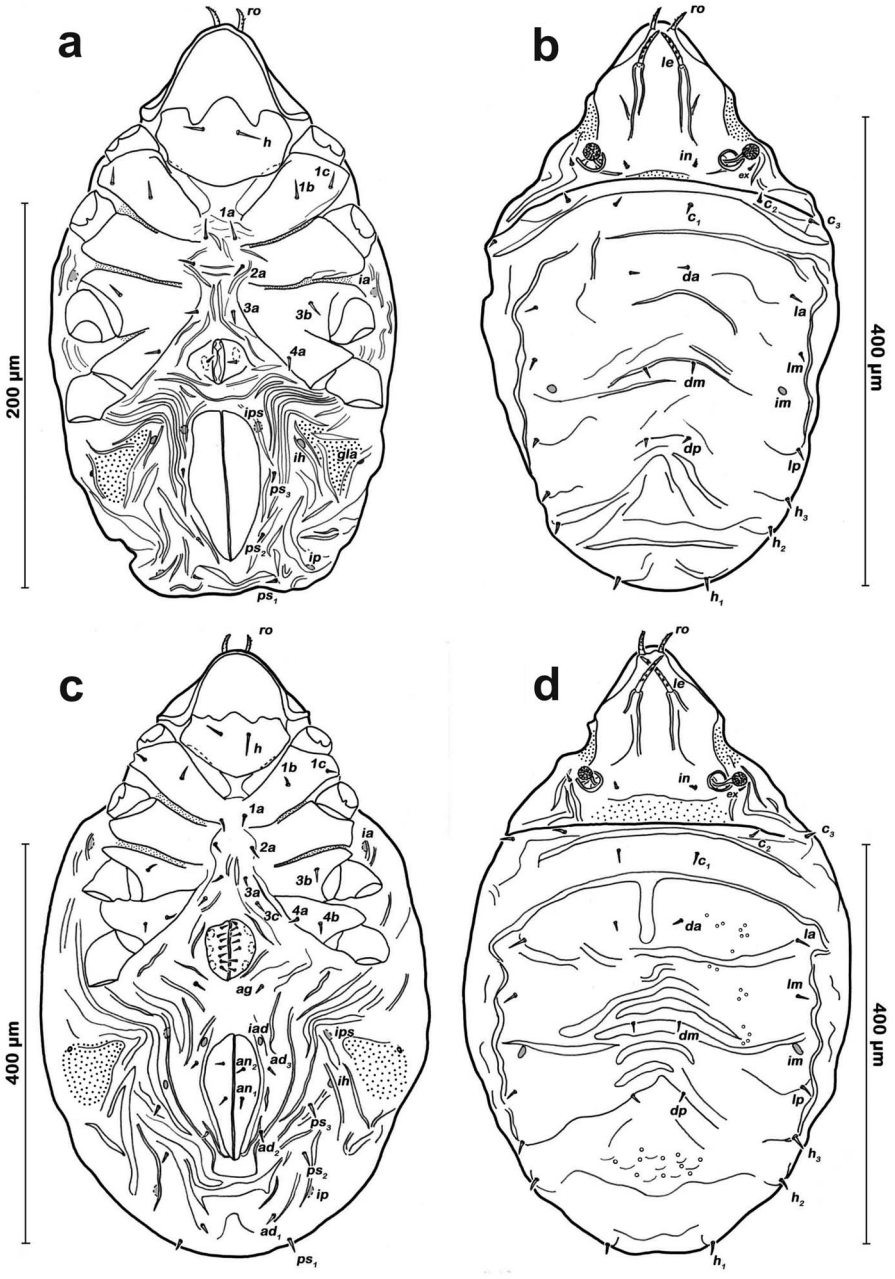
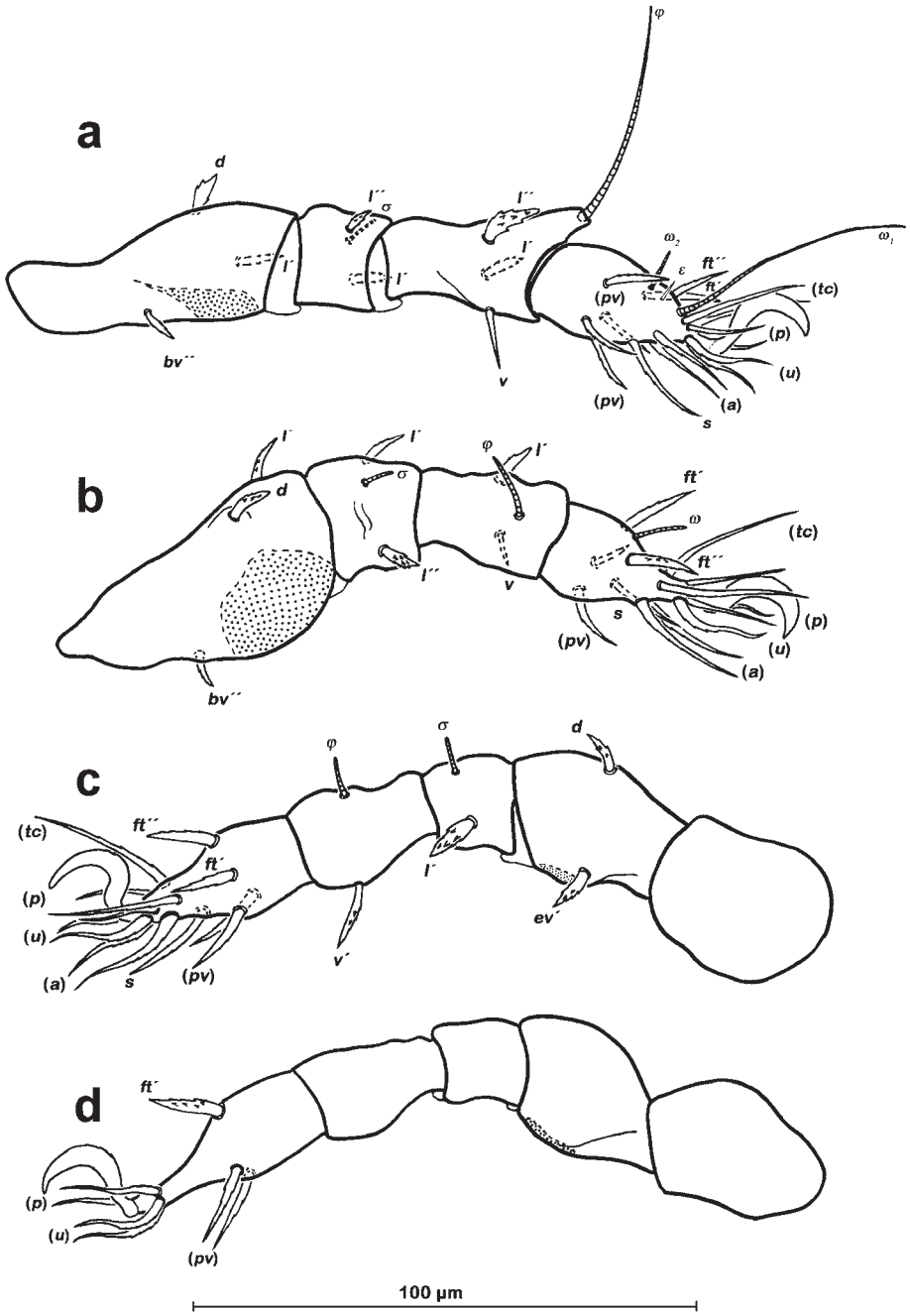


Fig. 10. *Unduloribates undulatus*, larva: anal region with vestigial seta h_3 (arrow)



Figs 11a-d. *Unduloribates undulatus*: a = protonymph ventral view, b = deutonymph dorsal view, c = tritonymph ventral view, d = tritonymph dorsal view. Legs and part of subcapitulum removed



Figs 12a-d. *Unduloribates undulatus*, protonymph, right legs in antiaxial view: a = leg I, b = leg II, c = leg III, d = leg IV. Trochanter omitted from legs I, II

GEOGRAPHIC DISTRIBUTION OF THE GENUS *UNDULORIBATES*

The genus *Unduloribates* is assumed to be a high alpine faunal element (CHOI 1994, WEIGMANN 2006) with some exceptions. *Unduloribates brevisetosus*, *U. hebes* and *U. medusa* show an exclusive occurrence in the Himalayas of Nepal (NÜBEL-REIDELBACH & WOAS 1992, AOKI 1965, PIFFL 1972). The type species *U. undulatus* can be found in alpine regions in the Alps of Austria (FRANZ 1943, 1954, SCHATZ 1989, SCHMÖLZER 1962, 1993, WILLMANN 1951), Italy (BERLESE 1914, SCHATZ 2008), and Switzerland (SCHWEIZER 1956), in the Sudeten mountain range (Giant Mountains) of Czech Republic (KUNST 1971), as well as in the Carpathians of northern Romania (BALOGH 1943) and the South-East Ukraine (GHILAROV & KRIVOLUTSKY 1975). A record of the latter species from Northwest Pakistan (HAMMER 1977) is the only finding outside of Europe. *Unduloribates (= Koreoribates) foliatus* (CHOI 1994) occurs in Southwest Korea (Mt. Mai) in an altitude of 400 m. The most recently described *U. dianae* was reported from North America: USA (Catskill and Adirondack Mountains of New York State) and different locations in Canada (Alberta, Newfoundland, Nova Scotia, Québec and British Columbia) (BEHAN-PELLETIER & WALTER 2009). Summarizing all records, the genus is considered to have a Holarctic distribution (Fig. 13) with a predomi-

Fig. 13. Overview of the geographical distribution of the genus *Unduloribates*; one symbol covers the records of a whole region

nantly occurrence in alpine habitats, whereas *U. dianae* also can be found in boreal forest litter, in the taiga, and tundra regions (BEHAN-PELLETIER & WALTER 2009). *Unduloribates undulatus* can also be found in a variety of different microhabitats as stony substrates, mosses and lichens, cushion plants, and alpine turfs. Little is known about the habitats of the other species; *Unduloribates brevisetosus* was found in an *Abies–Betula* forest and *U. medusa* in dwarf-shrub heaths.

DISCUSSION

Knowledge about the juveniles of *Unduloribates* species is scarce; only PIFFL (1972) gave information about the larva and nymphs of *U. medusa* and BEHAN-PELLETIER and WALTER (2009) provided information on the juveniles of *U. dianae*. The habitus of immatures of both species is quite similar to that of the juvenile stages of *U. undulatus*, as for example the keel-like lamellae, the shape of the prodorsum and the gastronotic plication. But there are differences in the shape of some setae and in the number of epimeral setae. The juveniles of *U. dianae* exhibit spinose and broad notogastral setae, as well as spinose interlamellar setae. There is no neotrichy in the genital setation of the nymphs of *U. dianae* and their sensillus is clavate. The juveniles of *U. undulatus* show more robust and spinose lamellar as well as rostral setae than *U. medusa*. The notogastral setae are all shaped the same as in *U. undulatus*, whereas the size of the setae of *U. medusa* increases from anterior to posterior. *Unduloribates medusa* exhibits already in the deutonymphal and the tritonymphal stage more setae on epimeres III and IV, which is not surprising as the adult shows a conspicuous epimeral neotrichy. The larval setae h_3 are developed as vestiges in *U. undulatus* whereas in *U. medusa* and *U. dianae* these setae are missing. Porose areas on the legs, prodorsum and ventral region next to orifice of opisthonotal gland are shared by the juveniles of *U. undulatus* and *U. dianae*, but these characteristics may have been overlooked in *U. medusa*. NORTON and BEHAN-PELLETIER (1986) placed the Unduloribatidae as the second family in the Phenopelopoidea. Their diagnosis for this group comprises some characters of the immatures, as for example plicate integument, carinate opisthosomal dorsum, paraproctal atrichosy in larva, protonymph and deutonymph and the loss of seta *d* on those tibiae and genua having a respective solenidion. The instars of *U. medusa*, *U. dianae* and *U. undulatus* match these features and therefore the inclusion of *Unduloribates* in the Phenopelopoidea seems justified. Furthermore the exochorion of *U. undulatus* as well as of *U. dianae* (BEHAN-PELLETIER & WALTER 2009, Fig. 11) and that of an undetermined *Eupelops* species shows a similar thick layer with deep and broad furrows; only the re-

ticulation pattern of the furrows is different (Figs 9a, b). KRISPER *et al*. (2008) have already shown that similar basic exochorion structures are present in related taxa and that only the fine structure is species specific.

NÜBEL-REIDELBACH and WOAS (1992) considered the possibility of all nominal *Unduloribates* species being instead a single polytypic species with a strong morphological plasticity, as was later claimed for *Tectocepheus velatus* (MICHAEL, 1880) (NÜBEL-REIDELBACH 1994). But they further argued that this was quite unrealistic because there were only four species known worldwide at that time and these were easy to distinguish. Table 2 compares *U. undulatus* with the other species. *Unduloribates medusa* (PIFFL 1972) is the most easily distinguished, due to its name-giving morphological character of epimeral neotrichy: it has seven pairs of long and serpent like setae on epimera III and IV. But also the broadened and spinose interlamellar and notogastral setae and the very long aggenital setae are diagnostic. *Unduloribates brevisetosus* is unique in having very short interlamellar and notogastral setae (NÜBEL-REIDELBACH & WOAS 1992). Another difference is the short and broad lenticulus which is also present in *U. hebes* (AOKI 1965). This latter species exhibits an almost smoothly rounded anterior margin of lamellar cusps, which is unique in the genus. *Unduloribates dianae* shows a unique irregularly tuberculate, thick, blocky cerotegument facilitating the determination of this species. All five species differ in their epimeral setation and the chaetome of their legs as far as it is specified in the descriptions, although the latter character needs more careful study. Nevertheless the determination of the species is unambiguous and their inclusion in the genus *Unduloribates* is certain.

In 1994 CHOI described a new species from Korea and proposed *Koreoribates* as the second genus of the family Unduloribatidae. SUBÍAS (2004) lists *Unduloribates* and *Koreoribates* as synonymous. *Koreoribates foliatus* shows all the diagnostic characters of the Unduloribatidae (NORTON & BEHAN-PELLETIER 1986) but furthermore it conforms also exactly with the diagnosis of the genus *Unduloribates* (BEHAN-PELLETIER & WALTER 2009). Differences, such as the foveolate cuticular structure and the leaf-shaped lamellar setae, seem to be species-specific, rather than genus-specific characters. SUBÍAS (pers. comm.) used the same arguments to synonymise *Koreoribates* with *Unduloribates* in his systematic list of oribatid mites (SUBÍAS 2004) and we agree with his decision.

The introduction of a new superfamily Unduloribatoidea including the families Unduloribatidae, Eremaeozetidae and Idiozetidae by SUBÍAS (2004) is founded on the shared presence of thick cerotegument and large broad lamellae; but, BEHAN-PELLETIER and WALTER (2009) stated that these characters are not synapomorphic and are subject to homoplasy in Brachypylina. Furthermore, the comparison of the juveniles of *Unduloribates* with nymphs of *Eremaeozetes* (SCHATZ 2001) reveals

Table 2. Comparison of certain morphological features of *Unduloribates* adults. * Chaetome from trochanter to tarsus in first parentheses and solenidia from genu to tarsus in second parentheses. In AOKI (1965) and NÜBEL-REIDELBACH & WOAS (1992) solenidia were included in chaetome, for better comparison solenidia are excluded above. Setation of leg II of *U. medusa* taken from PIFFL's depiction of the leg.

	U. undulatus (BERLESE, 1914)	*U. medusa* PIFFL, 1972	*U. hebes* AOKI, 1965	*U. brevisetosus* NÜBEL-REIDELBACH et WOAS, 1992	*U. dianae* BEHAN-PELLETIER et WALTER, 2009	*U. foliatus* (CHOI, 1994)
notogastral setae	10, long, smooth	10, long, spinose	10, long, smooth	10, short, smooth	10, short, spinose	10, long, spinose
lenticulus	slender, longish	slender, longish	short, broad	short, broad	broad, longish	short, broad
pteromorphs	rounded end	rounded end	acuminate end	rounded end	acuminate end	rounded end
lamellae	notched	notched	round	notched	notched	notched
interlamellar setae	long, spinose	long, broad, spinose	medium, spinose	short	short, spinose	short
epimeral setation	3–1–3–2	3–2–7–7	2–2–3–2	3–1–3–3	3–1–3–2	3(2?)–1–3–1 (2?)
genital setation	9 pairs	9 pairs	9 pairs	9 pairs	6 pairs	6 pairs
aggenital setae	short	long	short	short	short	short
leg I *	(1–5–3–4–18)(1–2–2)	?	(?–4–3–3–18)(1–2–2)	(?–5–3–4–19)(1–2–2)	(1–5–3–4–18)(1–2–2)	?
leg II*	(1–5–3–4–15)(1–1–2)	(?–4–2–4–14)(1–1–2)	(?–4–3–4–14)(1–1–2)	?	(1–5–3–4–15)(1–1–2)	?
leg III*	(2–4–1–3–15)(1–1–0)	?	(?–3–1–3–12)(1–1–0)	?	(2–3–1–3–15)(1–1–0)	?
leg IV*	(1–2–2–3–12)(0–1–0)	?	(?–2–2–3–12)(0–1–0)	(1–2–2–3–12)(0–1–0)	(1–2–2–3–12)(0–1–0)	?

obvious differences. The habitus is completely different although the immatures of both genera are plicate. According to the description (SCHATZ 2001) the instars of *Eremaeozetes* are lacking exobothridial setae, porose areas on the body and the legs; furthermore, the development of epimeral and setation of ano-genital region (no paraproctal atrichosy in the deutonymph!) is strikingly different. Another interesting and important divergence is that the protonymphs of *Eremaeozetes* show setae on femur, genu and tibia of leg IV, whereas these leg segments are "naked" in the majority of oribatid mites (GRANDJEAN 1946). All these facts reject a close relation of the families Unduloribatidae and Eremaeozetidae. Therefore, we agree with NORTON and BEHAN-PELLETIER (1986) as well as with BEHAN-PELLETIER and WALTER (2009) who retained the Unduloribatidae within the Phenopelopoidea.

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