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Construction of the Phylogenetic Model for the Genera of the Tribe Arctiini (Lepidoptera, Arctiidae) with the SYNAP Method

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Abstract—A new scheme of the phylogeny of the tribe Arctiini is proposed. The Western Mediterranean genus *Atlantarctia* is considered the most primitive one in the tribe; the rest of genera form two large clades *Arctia–Pericallia* and *Gonerda–Platyprepia*. The first clade is supposed to have been subjected to radiation in western Eurasia, and the second clade, in Asia and North America in the Palaeogene when the eastern part of Asia was isolated from western Eurasia. Subsequently, most probably in the Neogene-Pleistocene, representatives of both clades spread over the whole Eurasia and North America. The Arctiini fauna of the tundra zone, which includes the genera *Acerbia* and *Pararctia*, was formed in Asia and North America, whereas the subboreal fauna (both steppe and nemoral) originated in western Eurasia. The boreal genus *Borearctia* has most likely also originated in Asia.

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The present communication is part of a series of publications dealing with the elaboration of phylogenetic hypotheses for the tribes of the subfamily Arctiinae. Earlier the cladystic model was created for the more primitive tribe Callimorphini (Dubatolov, 2006). The tribe Arctiini is regarded here in the narrow sense based on the classification proposed for this subfamily (Dubatolov, 1990). It includes 17 genera (see Table) inhabiting the Palaearctic, 5 of them found in Nearctic and 4 occurring in the high mountains along the border with the Oriental region. The only non-Palaearctic genus belonging to this tribe is the endemic of the Nearctic, the monotypical genus *Platyprepia* occurring in the Cordilleras. In comparison with the tribe Callimorphini, the tribe Arctiini is characterized by the following apomorphies: complete reduction of the membranous process of valva (brachiola); development of basal processes of transtilla (peniculi); concave-convex valvae; presence of a single narrow non-flattened apical process of valva (two latter characters are the autapomorphies of Arctiini).

MATERIAL AND METHODS

All the taxa of the generic rank known in the world fauna of the tribe Arctiini were analyzed based on 33 characters of general appearance, genital structures (of both sexes), and the type of wing pattern. For these characters, vectors of evolution from plesiomorphic to apomorphic states were hypothesized. Definition of plesiomorphic states of characters was carried out by their comparison with those of the representatives of the tribe Callimorphini regarded as an outer group. The list of the characters used is given below. Character numerals correspond to those in the proposed cladogram; gaps in numeration have appeared due to exclusion of several initially formulated characters from the final analysis. The matrix of the distribution of the states of characters among the genera is given in table.

(1) Pectens on antennae: long, antennae pectinated (plesiomorphic state); short, antennae serrated (apomorphic state).

(2) Presence of pectens on antennae: present (plesiomorphic state), absent (apomorphic state).

(3) Shape and size of eyes: large and hemispheroid (plesiomorphic state); rather small and ovate (apomorphic state).

(4) Reduction of eyes: not developed (plesiomorphic state); developed (apomorphic state).

(5) Pubescence of eyes: absent (plesiomorphic state); present (apomorphic state).

Distribution of plesiomorphic (P) and apomorphic (A) states of characters in tribe Arctiini

Genus	No. of character												
	1	2	3	4	5	6	9	10	11	12	13	14	15
Parasemia Hübner, [1820]	P	P	A	A	A	P	P	P	P	A	A	P	P
Hyphoraia Hübner, [1820]	P	P	A	P	A	P	P	P	P	A	P	P	A
Platarctia Packard, 1864	B	P	A	P	A	P	A	A	P	A	A	P	P
Pararctia Sotavalta, 1965	A	P	A	A	A	P	A	A	P	A	A	P	P
Borearctia Dubatolov, 1984	A	P	A	A	A	P	P	P	P	A	A	P	P
Sinoarctia Dubatolov, 1987	P	P	A	A	P	A	B	B	P	A	A	P	P
Acerbia Sotavalta, 1963	A	P	A	A	P	P	A	A	P	A	A	A	P
Platyprepia Dyar, 1897	A	A	A	A	A	P	A	A	P	A	A	A	P
Oroncus Seitz, 1910	A	A	A	A	P	P	P	P	P	A	A	A	P
Orontobia de Freina, 1997	A	P	A	A	P	P	P	P	P	A	A	A	P
Gonerda Moore, 1879	P	P	P	P	P	B	P	P	P	A	A	P	P
Preparctia Hampson, 1901	P	P	P	P	P	P	A	A	P	A	A	A	P
Atlantarctia Dubatolov, 1990	P	P	P	P	P	P	A	A	P	P	P	P	A
Arctia Schrank, 1802	P	P	B	B	P	P	P	A	P	A	A	B	P
Epicallia Hübner, [1820]	P	P	A	P	P	P	P	A	P	A	A	P	A
Eucharia Hübner, [1820]	P	P	A	P	P	B	A	A	A	A	A	P	P
Pericallia Hübner, [1820]	A	P	P	P	P	P	A	A	A	A	B	B	P
Weight of character	1	1	1	1	1	1	1	1	2	2	1	1	1

Genus	No. of character												
	16	17	18	19	20	21	22	23	24	25	26	27	29
Parasemia Hübner, [1820]	P	A	P	P	A	A	P	P	B	A	A	P	A
Hyphoraia Hübner, [1820]	P	A	A	P	P	A	P	P	A	A	P	P	A
Platarctia Packard, 1864	P	A	B	P	P	A	P	P	B	P	A	P	P
Pararctia Sotavalta, 1965	P	A	B	P	P	A	P	P	P	M	A	P	P
Borearctia Dubatolov, 1984	P	A	P	P	P	M	M	A	P	M	A	P	P
Sinoarctia Dubatolov, 1987	P	P	P	P	P	M	A	M	P	M	A	P	P
Acerbia Sotavalta, 1963	P	A	B	P	B	P	P	P	P	M	B	B	P
Platyprepia Dyar, 1897	P	P	P	P	P	P	P	P	B	P	A	P	P
Oroncus Seitz, 1910	P	A	B	P	P	A	P	P	B	M	P	P	P
Orontobia de Freina, 1997	P	A	P	P	P	P	P	P	A	M	A	B	P
Gonerda Moore, 1879	P	A	P	P	A	A	P	M	P	M	A	P	P
Preparctia Hampson, 1901	P	A	P	P	B	A	P	M	P	M	A	B	P
Atlantarctia Dubatolov, 1990	P	M	A	M	P	A	P	P	P	M	P	P	P
Arctia Schrank, 1802	P	P	B	P	P	A	P	P	P	M	B	B	P
Epicallia Hübner, [1820]	A	P	P	P	P	A	P	P	A	P	P	P	P
Eucharia Hübner, [1820]	P	M	A	M	P	A	P	P	B	M	A	P	P
Pericallia Hübner, [1820]	P	A	P	A	P	A	P	P	A	M	P	P	P
Weight of character	1	1	1	1	1	1	1	1	1	3	1	1	3

Notes: B,- polymorphism; M, vector of character change absent; ?, state of character undetermined.

(6) Female wings: well developed (plesiomorphic state); shortened (apomorphic state).

(9) Uncus in length: long (plesiomorphic state); shortened (apomorphic state).

(10) Uncus in shape: pointed (plesiomorphic state); widened (apomorphic state).

(11) Posterior part of tegumen: ordinary (plesiomorphic state); widened (apomorphic state).

(12) Apical process of valva: below apex (plesiomorphic state); at apex (apomorphic state).

(13) Shape of cross-section of apical process of valva: flattened (plesiomorphic state); rounded (apomorphic state).

(14) S-shaped curvature of apical process of valva: absent (plesiomorphic state); present (apomorphic state).

(15) Elongated pointed ventral angle of valva: absent (plesiomorphic state); present (apomorphic state).

(16) Asymmetry in valval structures: not developed (plesiomorphic state); developed (apomorphic state).

(17) Peniculi and sclerotization of transtilla: both present (plesiomorphic state); only peniculi present (apomorphic state).

(18) Peniculi: developed (plesiomorphic state); reduced (apomorphic state).

(19) Number of processes of peniculi: 1 pair (plesiomorphic state); 2 pairs (apomorphic state).

(20) Median process of juxta: present (plesiomorphic state); absent (apomorphic state, novelty).

(21) Dark bands on fore wings: narrow, uninterrupted (plesiomorphic state); divided into spots (apomorphic state).

(22) Dark markings on wings (first variant): oriented transversally (plesiomorphic state); oriented longitudinally but not along veins (apomorphic state).

(23) Dark markings on wings (second variant): oriented transversally (plesiomorphic state); oriented longitudinally along veins (apomorphic state).

(24) Hypertrophy of dark pattern on fore wings: not developed (plesiomorphic state); developed (apomorphic state).

(25) Wing pattern between Cu and A veins: a series of small spots (plesiomorphic state); a long streak especially pronounced at wing base (apomorphic state).

(26) Indented area at aedeagus apex: absent (plesiomorphic state); present (apomorphic state).

(27) Keels at the top of apical process of valva: absent (plesiomorphic state); present (apomorphic state).

(29) Postvaginal plate: approximated to ostium (plesiomorphic state); distanced from ostium (apomorphic state).

(30) Preostial folds in length: short (plesiomorphic state); long (apomorphic state). Uncomplicated structure is regarded to be plesiomorphic state as compared to complicated structure.

(31) Preostial folds in shape: ovate or triangular (plesiomorphic state), with a distinctive apical lobe (apomorphic state). Uncomplicated structure is regarded to be plesiomorphic state as compared to complicated structure.

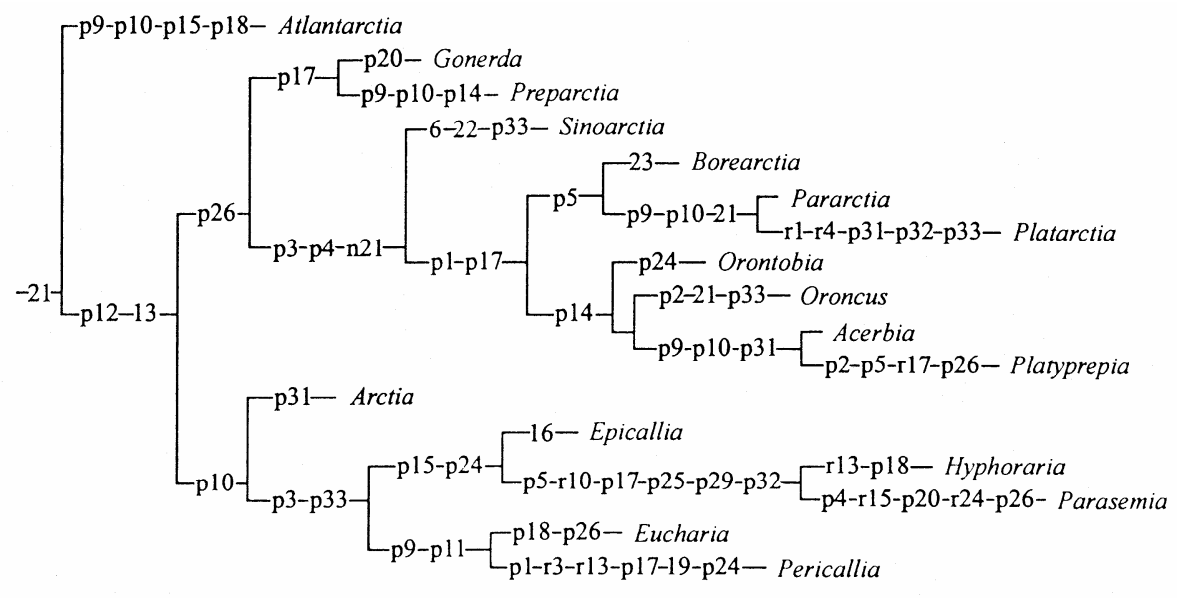
(32) Bursa copulatrix: large (plesiomorphic state); small (apomorphic state).

(33) Bulla seminalis: large (plesiomorphic state); small (apomorphic state).

For phylogenetic analysis, the SYNAP method elaborated by Baikov (1999) was used, using the SYNAP 420 program. In this method and program, unlike other analogous methods, assessment of trends of the character changes from plesiomorphic to apomorphic state is specified personally by the researcher. This allows a more thorough approach to determination of plesiomorphies, based not only on a single outer group whose certain representatives can possess characters in apomorphic state. In the framework of the method used, reversions, equated with apomorphies, are also more adequately understood. One more significant positive trait of the SYNAP method is a possibility to designate "weight" to characters, which is important in cases of novelties which are absent in all outer groups. Such a unique character will bear the maximum weight as its carriers are undoubtedly closely related. The cladogram obtained is represented in figure.

RESULTS

The most isolated position within the tribe is occupied by the genus *Atlantarctia*, which is considered by European taxonomists within the genus *Arctia* (de Freina, Witt, 1987). The archaic structure of the flat-



Cladogram of the tribe Arctiini obtained by the SYNAP method. Numerals correspond to character numerals given in the text; *n*, state of character not defined; *p*, parallelism; *r*, reversion.

tened valvae as well as short and flattened apical process shifted to the costal margin of valva allow rapprochement of this genus with the representatives of the primitive tribe Callimorphini. However, *Atlantarctia* is characterized by autapomorphies, the most reliable among them being shortened uncus and presence of elongated tapered ventral angle of valva.

Other genera of the tribe form two large clades. Within the first one, including taxa typical of the plains of moderate altitudes, the isolated position of the generic group *Arctia–Epicallia–Parasemia–Hyphoraia–Eucharia–Pericallia* is observed. Most of these genera are characterized by a shortened and basally widened uncus, which is secondarily elongated only in *Parasemia–Hyphoraia*. The aforementioned genera are split into 4 major subgroups. In *Arctia*, the preostial folds possess a distinctive apical lobe; in *Eucharia–Pericallia*, a pronounced hypertrophy of the tegumen (with the development of peculiar dorsal prominences) and associated noticeable shortening of the uncus take place; in *Parasemia–Hyphoraia*, numerous synapomorphies are revealed, the most pronounced among them being the presence of hairs on eyes, confluence of pale spots on fore wings into a longitudinal streak between Cu and A veins, postgenital plate distanced from ostium, and shortened bursa copulatrix. The genus *Epicallia* is approximated to the latter pair of genera by presence of elongated tapered ventral angle of valva and hypertrophy of dark pattern on fore wings.

The remaining genera of the tribe, occurring in the Holarctic mainly in the northern and mountainous areas of Asia and North America, form a graduated clade. The genera *Gonerda–Preparctia* seem to be most closely related to this clade, which is testified to a very similar wing pattern and presence of peniculi accompanied with the absence of transtilla. The genus *Sinoarctia* occupies an isolated position, judging from such characters as shortened wings in females, longitudinal dark pattern of fore wings, and diminished bulla seminalis. The group of *Borearctia–Pararctia–Platarctia* is characterized by the presence of hairs on eyes, whereas *Oroncus–Orontobia–Acerbia–Platyprepia*, by curved apical process of valva.

Unfortunately, due to absence of material, I failed to examine female genital structures in the genera *Preparctia* and *Orontobia*. For this reason, the part of cladogram, uniting genera *Gonerda–Platarctia–Platyprepia*, should not be regarded as completely proved.

DISCUSSION

Occurrence of the most primitive representatives of the tribe Arctiini in the Mediterranean makes it possible to suggest the European, instead of Siberian-American, origin of the tribe. The division of two large clades *Arctia–Pericallia* and *Gonerda–Platyprepia* is associated by the author with the isolation of their ancestors as early as the Paleogene in the period of division of Eurasia into two parts and existence of the terrestrial Beringian bridge, the ancestors of the

first clade located in western Eurasia and those of the second clade in Asia and North America. This dating is upheld by the finding of the genus *Stauropolia* referred to this tribe by Dubatolov (1996) and, judging from the wing pattern, belonging to the second clade from the Miocene of Ciscaucasia. Later, most probably in the Neogene and Pleistocene, representatives of both the clades have radiated throughout Eurasia and North America.

Formation of the Arctiini fauna (including genera *Acerbia* and *Pararctia*) in the tundra zone took place in Asia and North America, which corresponds to the data on the origin of tundra landscapes in the second half of the Pliocene in Beringia (Fradkina, 1995). The origin of the Transpalaearctic boreal genus *Borearctia* is most probably also associated with Asia. Meantime the subboreal fauna of Arctiini, as well as the steppe and nemoral faunas, were formed in the western part of Eurasia.

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