PTEROMALUS APUM (RETZIUS) AND OTHER PTEROMALID (HYM.) PRIMARY PARASITOIDS OF BUTTERFLY PUPAE IN WESTERN EUROPE, WITH A KEY

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Pteromalus apum (Retzius in De Geer) (= *venustus* Walker) is well known as a gregarious parasitoid in cocoons of leaf-cutter bees (Apoidea, Megachilidae) in Europe and America (Graham, 1969; Burks, 1979), but an association with lepidopteran hosts does not appear to have been reported previously. In this paper we present morphological data on six separate collections of parasitoids, attributed to *P. apum*, which were reared from pupae of *Gonepteryx* (Pieridae) and *Melitaea*, *Hypodryas* and *Eurodryas* (Nymphalidae, Melitaeinae). This material from butterfly pupae is compared with specimens in two collections reared from *Megachile* cocoons.

A key is provided to adult Pteromalidae that are known to behave as primary parasitoids of butterfly pupae in western Europe.

Pteromalus apum material studied

Collection 1: 1♂ 7♀♀, ex cocoon(s) *Megachile centuncularis* (L.), Wye (Kent?), v.1918, *D.J. Jackson*. No further data on provenance are available.

Collection 2: 1♂ 4♀♀, from sample of 30 individuals ex cocoon(s) *Megachile pyrenaica* Lepeletier, Treignes, Belgium, 8.iv.1993, Baugnée. These specimens were submitted by Dr *P. Dessart*, having been reared in Belgium from *M. pyrenaica* cocoons in culture.

Collection 3: 6♂♂ 33♀♀, ex one pupa *Gonepteryx rhamni* (L.). The larva was collected in Westmorland and pupated in Middleton, Manchester. No further data are available.

Collection 4: 3♂♂ 40♀♀ (2♂♂ 20♀♀ from one pupa), part of a larger sample ex *G. rhamni* pupae, Frizinghall, Bradford, W. Yorkshire, emerged viii.1993, *D. Parkinson* and *S. Stead.*

The brimstone butterfly has only recently bred in the Bradford area of West Yorkshire, following planting of *Frangula alnus*. A potted plant, standing on a patio, had 12 caterpillars in June 1993 and 10 pupae were subsequently located. Nine of these pupae produced broods of *P. apum* towards the end of August. A number of unidentified aculeates, possibly including *Megachile*, were nesting in a wall behind the food plant and in a bamboo cane supporting it (D. Parkinson, pers. com.).

Collection 5: 12♀♀ (of a total 14♀♀), ex one pupa *Eurodryas aurinia* (Rottemburg) and one pupa *Hypodryas maturna* (L.), Torphyttan, Lindesberg, Vastmanland, Sweden, emerged 26.vi.1993, *C. Eliasson.*

H. maturna was collected as a larva and kept until pupation in an outdoor cage where, presumably, it was parasitised; *E. aurinia* was found as a pupa in an unusually exposed situation and was most probably already parasitised when collected.

All the parasitoids were thought at first to be from *E. aurinia* pupae, and were mounted together on a single card. Only later was it discovered that one of the two host pupae was *H. maturna*. The sample is clearly divisible into two forms of *P. apum*, designated forms A and B (table 1). Form A (7 specimens) has the antennal flagellum shorter, scutellum dorsally flattened, propodeum with median carina usually indicated and gaster longer; form B (5 specimens) has a longer antennal flagellum, more convex scutellum, no median carina and shorter gaster. It is very probable that all specimens of each one of these forms comprised a brood, but it is not known which of the two hosts produced form A and which form B.

Collection 6: 24♂♂ 27♀♀, ex one pupa *Eurodryas aurinia*, Var, France, leg. 6.v.1976, emerged 18.v.1976, *P.W. Cribb*.

Collection 7: 10♂♂ 17♀♀, from broods ex pupae *Melitaea cinxia* (L.) collected as larvae in June 1993, Stålsby, Finström, Åland, Finland, and kept at Helsinki in rearing cages, *M. Kuussaari, G. Lei* and *J. Poyry*.

The *M. cinxia* were parasitised when they became pupae. 55 parasitised pupae yielded broods of *P. apum* ranging between 6 and 30 per pupa (average 21.14±2.91). A sample of 159 *P. apum* comprised 32♂♂ and 127♀♀. In 1994, 6.7% of *M. cinxia* pupae placed in their natural habitat were parasitised (Guangchun Lei, pers. com.).

Collection 8: 18♂♂ 33♀♀, ex one pupa *Melitaea didyma* (Esper), Digne, Alpes de Haute Provence, France, leg. vii.1968, emerged 1968, *M.R. Shaw*.

TABLE 1. — MORPHOLOGICAL DATA ON *PTEROMALUS APUM* REARED FROM DIFFERENT SOURCES. For further explanation of the characters, see the text.

Coll. & Host	Scape height	Fun.I :ped.	Ped.+ flag. :hd	Hd b:l	Gst. l:b	Gst. :ms.	M:st	Pm:m	Med. car.	Prop. slope
1 *M. centuncularis*	below	0.92	0.80	2.16	1.89	1.35	1.03	1.33	basal ¼	40°
2 *M. pyrenaica*	below	1.11	0.90	2.08	1.84	1.11	1.10	1.27	complete	35°
3 *G. rhamni*	below	1.00	0.80	2.11	1.70	1.29	1.17	1.21	basal ¼	40°
4 *G. rhamni*	below	1.17	0.81	2.39	2.22	1.23	1.35	1.04	basal ¼	40°
5 *E. aurinia* and *H. maturna*										
Form A	bottom	1.00	0.79	2.22	1.63	1.13	1.00	1.39	complete	30°
Form B	top	1.71	1.02	2.22	1.29	0.93	1.11	1.33	absent	50°
6 *E. aurinia*	middle	1.45	0.91	2.17	1.92	1.20	1.00	1.37	absent	35°
7 *M cinxia*	middle	1.67	0.88	2.26	2.17	1.42	1.00	1.42	complete	45°
8 *M. didyma*	middle	1.42	0.99	2.15	2.48	1.60	1.11	1.35	complete	45°

MORPHOLOGY

Details and measurements of morphological characters of female specimens from each of the eight collections are given in Table 1. Whilst all specimens from a single brood tend to be of very uniform structure, there is considerable morphological variation between individuals from different collections. Those characters in which this variation is most pronounced were examined. Males did not appear to vary in any additional characters and they are omitted from this analysis.

Scape height: where the apex of the scape reaches, in the vertical position, in relation to the median ocellus.
Fun.l : ped.: ratio of the lengths of the first funicle segment and the pedicel.
Ped.+flag. : hd: ratio of the length of the pedicel plus flagellum to the breadth of the head.
Hd b : l: ratio of the breadth of the head to its length when measured in dorsal view.
Gst. l : b: ratio of gaster length to breadth when measured in dorsal view.
Gst. : ms.: ratio of gaster length to mesosoma length.
M : st: ratio of lengths of marginal and stigmal veins.
Pm : m: ratio of lengths of postmarginal and marginal veins.
Med. car.: expression of the median carina on the propodeum, whether absent, or present and complete or confined to the basal part of the sclerite.
Prop. slope: the angle at which, in lateral view, the dorsal surface of the propodeum inclines from the horizontal plane of the thorax, the latter taken as a line from the front of the pronotal collar to the front of the dorsellum. This line is approximately parallel to the tangent of the mesoscutum and scutellum. In some specimens, the dorsal surface of the scutellum is flattened longitudinally and transversely, and there is a correlation between the degree of flatness and the propodeal slope, specimens with flatter scutella having a smaller angle of slope.

DISCUSSION

Material reared from *Megachile*, which we take as 'standard' *P. apum*, is characterised by:

relatively short antennal segments (apex of scape not reaching the median ocellus, first funicle not or hardly longer than the pedicel, and length of pedicel plus flagellum distinctly less than breadth of head), more or less flattened scutellum (shallow propodeal angle of slope), and a rather short and broad gaster.

Specimens from *Gonepteryx* are very similar to those from *Megachile*, as is form A from collection 5 reared from either *Eurodryas* or *Hypodryas* in Sweden. The remaining material from pupae of fritillaries, including that from *E. aurinia* in France (collection 6), tends to have slightly longer antennae and a steeper propodeal slope.

It was thought initially that specimens reared from fritillary pupae in the wild represented a species distinct from *P. apum*, and that *P. apum* had included the British *Gonepteryx* in its host repertoire only through proximity to *Megachile*. Thus the parasitised *G. rhamni* pupae in Yorkshire may have been close to *Megachile* nests in a suburban garden. Furthermore, *P. apum* is frequently associated with buildings; it has quite often been found on windows inside houses in England and France, and the samples from *Megachile pyrenaica* in Belgium (collection 2), *Hypodryas maturna* in Sweden (part of collection 5) and *Melitaea cinxia* in Finland (collection 7) are from hosts cultured in a laboratory or maintained outdoors near buildings in rearing cages. However, whilst the synanthropic tendencies of *P. apum* could account for some of the cases of parasitisation of butterfly pupae, they fail to explain why *P. apum* has not been found to attack synanthropic *Pieris* or Nymphalidae (which are commonly hosts to *Pteromalus puparum* (L.)).

It is now believed that only one species, *P. apum*, is represented in the collections from *Megachile*, *Gonepteryx* and Melitaeinae and that these taxa are all regular components of its host range, notwithstanding the disparities between a cocoon of *Megachile* and a naked butterfly chrysalis. There is no convincing discontinuity in the morphological characters examined, and hosts of forms A and B of collection 5 were obtained at the same time and place: although one host was probably attacked after collection, it is highly probable that the forms are conspecific, even though they differ quite considerably in antennal length and gastral shape.

Graham (1969: 491) comments upon the variability of *P. apum* (as *P. venustus*) in the proportions of the antennal funicle segments and expression of the median carina on the propodeum. Our data also show the shape of the gaster to be very variable. Specimens from collection 8 are notable for their mostly exceptionally long and narrow gasters, although one small female (length <2.0 mm) has a gaster only 1.8 times as long as broad and 1.3 times as long as the mesosoma. Gastral shape is known to vary in other species of Pteromalidae (e.g. *Eulonchetron* (Askew, 1995))

It is concluded that *P. apum* is a variable species which attacks both *Megachile* and certain species of butterflies.

KEY TO PTEROMALIDAE WHICH ARE PRIMARY PARASITOIDS IN BUTTERFLY PUPAE

This key includes all species of Pteromalidae that we have seen reared as primary parasitoids of butterfly pupae in western Europe, although it is likely that some other species may be found to share this habit. Some Pteromalidae can behave as secondary parasitoids of butterflies, for example by attacking the cocoons of primary parasitoids, but the key includes only species believed to function regularly as primary parasitoids.

1. Forewing with postmarginal vein longer than stigmal and marginal veins; apical wing margin with fringing hairs 2

— Forewing with postmarginal vein not longer than stigmal vein and barely half the length of marginal vein; apical wing margin bare 4

2. Head seen from above with temples convex; clypeus with anterior edge medially deeply emarginate; stigmal vein distinctly curved, the stigma not clearly differentiated and about twice as far from origin of stigmal vein as from costal margin of wing; head and dorsum of thorax shining, with weakly raised sculpture (especially in ♀), partly engraved on scutellum. *Female* with gaster subcircular, apices of the ovipositor sheaths not reaching beyond last tergite. *Male* with external base of mandible strongly, convexly developed, the mouth opening enlarged and 5 to 6 times as broad as malar space; gaster with pale subbasal spot . . . . *Psychophagus omnivorus* (Walker)

Seen from *Polygonia c-album* (L.) (Britain: Northants., *J.H. Payne*) and *Strymonidia w-album* (Knoch) (Britain: Somerset, *A. Liebert*); more often a parasitoid of large moths that pupate at or below ground level.

— Head seen from above with temples almost straight; clypeus shallowly emarginate; stigmal vein almost straight, the stigma appearing as a more abrupt apical expansion of the vein and about 1.5 times as far from origin of stigmal vein as from costal margin of wing; head and thorax with strongly raised sculpture, less shining. *Female* with gaster apically pointed, apices of ovipositor sheaths visible in dorsal view. *Male* with bases of mandibles not unusually developed, mouth opening about 2 times as broad as malar space; gaster without a pale subbasal spot 3

3. Antenna with scape only slightly shorter than eye, reaching to level of vertex; flagellum almost filiform, funicle segments at least slightly elongate. *Male* legs (except coxae), and antennae at least ventrally, bright testaceous . . . . *Pteromalus puparum* (L.)

Seen from *Papilio machaon* L. (Britain), *Aporia crataegi* (L.) (France), *Pieris brassicae* (L.) (Britain, Germany, Spain), *P. rapae* (L.) (Britain, France), *Pontia daplidice* (L.)

(Britain), *Ladoga camilla* (L.) (Britain), *Vanessa atalanta* (L.) (Britain, France), *Aglais urticae* (L.) (Britain), *Nymphalis polychloros* (L.) (Britain, Germany), *Argynnis adippe* (D. & S.) (Britain), *Pandoriana pandora* (D. & S.) (Tenerife) and *Libythea celtis* (Laicharting) (Turkey); also material reared as hyperparasitoids of *'Apanteles'* ex *Zygaena* (Askew, 1970). Additionally reported from *Cynthia cardui* (L.) (Graham, 1969), *Melitaea cinxia* (Guang-Chun Lei, pers. com.). This is an abundant and widespread species in Britain, often troublesome in infesting captive breeding stocks of butterflies (seen from *Papilio xuthus* L. and *P. polytes* L., as well as from several of the foregoing).

— Antenna with scape much shorter than an eye, reaching at most to median ocellus; flagellum less slender, the distal funicle segments subquadrate. *Male* legs and antennae darker, the femora more or less fuscous ..... *Pteromalus apum* (Retzius in De Geer)

Seen from *Gonepteryx rhamni, Eurodryas aurinia, Hypodryas maturna, Melitaea cinxia* and *M. didyma*, as detailed above.

4. Forewing sparsely hairy, upper surface of disc with hairs not extending proximally below costal cell; genae compressed with a sharp edge above mandibles; head in profile protuberant to level of antennal toruli, which are below lower margins of eyes, and strongly receding to mouth; occipital carina absent; plicae of propodeum strongly curved .... *Coelopisthia caledonica* Askew

Seen from *Melitaea cinxia* (Finland, *G. Lei*); probably normally a parasitoid of Noctuidae.

— Forewing normally hairy, upper surface of disc with hairs extending proximally below apex of costal cell; genae not compressed above bases of mandibles, rounded into occipital surface; head in profile not protuberant, antennal toruli slightly above lower margins of eyes and face not receding strongly between toruli and mouth; occipital carina more or less indicated; plicae of propodeum anteriorly almost parallel .... *Dibrachys* spp.

Although capable of being primary parasitoids of Lepidoptera pupae, species of *Dibrachys* are most commonly recorded as secondary parasitoids through Ichneumonoidea cocoons and Tachinidae puparia. The genus is included here on the basis of the comment in Graham (1969: 813) that *D. boarmiae* (Walker) has been reared as a primary parasitoid of *Pieris brassicae*, and the expectation that both *D. boarmiae* and *D. cavus* (Walker) will occasionally include butterfly pupae in their extremely wide host ranges.

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[*Addendum.* After this paper was written, we have seen a brood of *Pteromalus apum* reared from a pupa of the Heath Fritillary, *Mellicta athalia* (Rottemburg), collected in June 1984 at Greenscombe Wood, East Cornwall by Dr M.S. Warren. The brood comprises 2♂♂ 11♀♀ but seven of these are pupae or adults still within their pupal cases. The females most resemble those in collection 5 (form A) (Table 1), having a relatively short gaster, flattened scutellum and shallowly sloping propodeum with a complete median carina. The antennal scape, however, does not reach to the median ocellus. *M. athalia* represents an addition to the host list of *P. apum*. A further 5 pupae of *Hypodryas maturna* were parasitised by *P.*

apum (form A) on 13.vi.1996, 3 days after the larvae taken from the field at Lindesberg (see coll. 5) had pupated. A ♀ *P. apum* was captured from the back of a pupa on this date. Brood sizes were 2♂♂ 5♀♀, 3♂♂ 7♀♀, 5♂♂ 22♀♀, 6♂♂ 42♀♀, 4♂♂ 55♀♀. — R.R.A. & M.R.S. *October 1st*, 1996.]

REVIEW

'MEDICAL ENTOMOLOGY FOR STUDENTS' By M.W. SERVICE. Chapman & Hall, London; x + 278 pp. 98 figs. Pbk., ISBN 0 412 71230X. 1996. Price £19.99.

Those of us who teach courses on medical entomology are well aware of the paucity of basic text books which we can honestly recommend to students. Until it went out of print, this niche was admirably filled by Mike Service's *Lecture Notes on Entomology* published by Blackwell Scientific Publications in 1986. Hence, medical entomology teachers and students alike should be extremely pleased that Chapman & Hall have now published an updated version entitled *Medical Entomology for Students*. At £19.99, this slim paperback is affordable to most students, giving it a significant advantage over its main competitor, *Medical and Veterinary Entomology* by D.S. Kettle, (1995, CAB International, £37.50). The only other serious contenders in this field are both weighty multi-author volumes which aim at a more specialist market and are priced accordingly: *The Biology of Disease Vectors* edited by B.J. Beaty & W.C. Marquardt (1996, University Press of Colorado, £51.50), and *Medical Insects and Arachnids* edited by R.P. Lane & R.W. Crosskey (1993, Chapman & Hall, £87).

Professor Service has organised the book traditionally, i.e. on taxonomic grounds, with a chapter on the identifying features, biology, disease relationships and control of each group of arthropod vectors. Not surprisingly, given their public health significance and the author's own research interests, mosquitoes receive the most attention, taking up almost a third of the text. The book is clearly written and is well illustrated throughout. Helpfully, each of the 20 chapters has its own brief reference list. The book assumes no specialist knowledge from the reader, and should be of interest to any student who requires a ready source of basic information on medical entomology. It may also be useful for physicians, nurses, health officials and community health workers.

My only quibbles with this book are those which often result from a single author textbook. It is very difficult for an individual to keep abreast of developments in such a wide field. Much of the text has been little altered since its previous incarnation, and some of the information provided is a little dated. This is most notable in the sections on control. A second problem common to single author texts is that minor errors inevitably appear in those sections which are not the author's speciality. Characteristic examples can be found in the chapter on phlebotomine sandflies. For example, Service writes that species in three out of five genera, *Phlebotomus, Lutzomyia* and *Sergentomyia*, suck blood from vertebrates. In fact, most taxonomists describe six phlebotomine genera, and *Brumptomyia* and *Warileya* certainly take vertebrate blood too. Another notable error is the reporting of *Lutzomyia amazonicus* as a leishmaniasis vector. In fact, there is no such species.

During the ten years that have passed since the publication of *Lecture Notes on Medical Entomology*, the disease burden caused by insect vectors has continued to rise and the requirement for training medical entomologists should remain a priority for all institutions with concern for public health. Despite all the advances in molecular biology and the laboratory sciences, there is a continuing need for specialists with the ability to identify insect vectors and to study their biology. One measure of the challenge faced by medical entomology is found in the increasing number of species recorded in each insect group. By comparing the new book with the 1986 version, we see, for example, that the number of mosquito species has increased in ten years from 3200 to 3450 and the number of blackflies from 1300 to 1600. The development of insecticide resistant vectors, drug resistant pathogens, and a changing environment bringing people into closer contact with sylvatic transmission cycles, have together significantly increased the danger posed by vector-borne diseases. *Medical Entomology for Students* serves a vital purpose by providing a readily accessible introduction to this important subject. — C.R. DAVIES