Crossing the borders of orders:

head anatomy of *Coniopteryx pygmaea* (Insecta: Neuroptera: Coniopterygidae) and convergent miniaturization effects in insects

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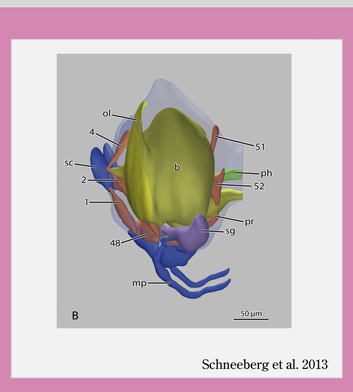
Coniopteryx pygmaea
original size

In many insect orders miniaturized forms evolved independently from larger ancestors. Structural, physiological and physical constraints lead to convergent modifications in the head anatomy.
***Coniopteryx pygmaea* Enderlein, 1906 with a body length of 1.5 mm is one of the smallest known lacewings. The aim of the present study is to figure out the influence of body size on the head anatomy of *C. pygmaea* through comparison with larger neuropteran species and miniaturized forms in other insect orders.**

The heads of *C. pygmaea* and of the neuropteran comparison material were imaged using X-ray microtomography (University of Vienna), semithin sections and SEM (JEOL JSM-6610; Natural History Museum Vienna). For 3D visualization the software Amira 5.1 was used.

Relative size of the brain

A certain number of neurons are required to retain the sensory, motor and humoral control of the brain. Thus the size of the brain in relation to the head capsule is increased (Beutel & Haas 1998).
Convergently developed in the orders Neuroptera, Diptera (Schneeberg et al. 2013), Hymenoptera (Polilov 2012), Strepsiptera (Beutel et al. 2005), Coleoptera (larvae: Beutel & Haas 1998), Thysanoptera (Mickoleit 1963: Fig. 7).



Schneeberg et al. 2013

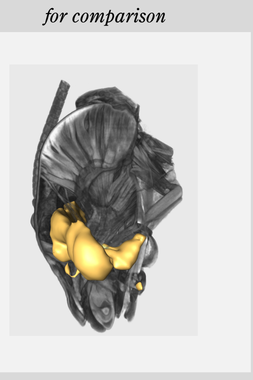
Diptera
Mayetiola destructor
body length: 2-3 mm

Neuroptera
Coniopteryx pygmaea
body length: 1.5 mm

Polilov 2012

Hymenoptera
Megaphragma mymaripenne
body length: 0.2 mm

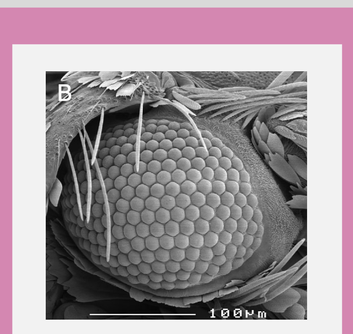
for comparison



Neuroptera
Polystoechotes punctatus
body length > 35 mm

Number and diameter of facets

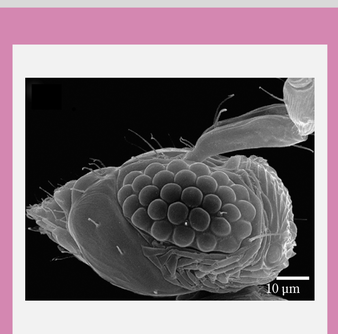
The size of the head also limits the size of the compound eyes. The number of the facets and their diameter are decreased (Fischer et al. 2013).
Convergently developed in the orders Neuroptera, Lepidoptera (Honkanen & Meyer-Rochow 2009), Hymenoptera (Polilov 2012), Coleoptera (Grebennikov 2008: Fig. 51), Diptera (Schneeberg et al. 2013: Fig. 1), Psocoptera (Meyer-Rochow & Mishra 2007: Fig. 1), males of Strepsiptera (Beutel & Pohl 2006: Fig. 1), Thysanoptera (Mickoleit 1963: Fig. 1).



Honkanen & Meyer-Rochow 2009

Lepidoptera
Ectoedemia argyropeza
body length ~ 2 mm
number of facets ~ 224
diameter of facets ~ 14 µm

Neuroptera
Coniopteryx pygmaea
body length: 1.5 mm
number of facets ~ 280
diameter of facets ~ 10 µm



Polilov 2012

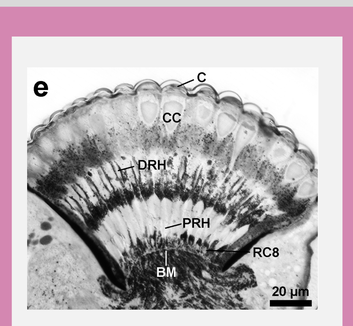
Hymenoptera
Megaphragma mymaripenne
body length: 0.2 mm
number of facets ~ 29
diameter of facets ~ 6.5 µm

for comparision

Neuroptera
Chrysoperla carnea
body length: 10-12 mm
number of facets ~ 1600
diameter of facets ~ 18 µm

Structure of compound eyes

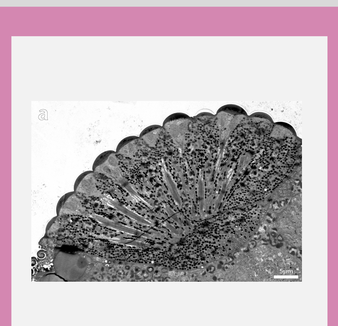
A certain size of the dioptic apparatus is necessary to focus the incident light on the underlying rhabdom (Fischer et al. 2010). As a consequence the dioptic apparatus projects into the head capsule and the ocular ridge becomes bell-shaped.
Convergently developed in the orders Neuroptera, Coleoptera (Polilov & Beutel 2009: Fig. 13C, Makarova & Polilov 2013: Fig. 1), Psocoptera (Meyer- Rochow & Mishra 2007: Fig. 4).



Fischer et al. 2013

Lepidoptera
Ectoedemia hannoverella
body length: 2.45 mm

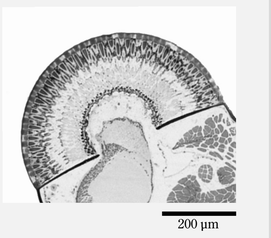
Neuroptera
Coniopteryx pygmaea
body length: 1.5 mm



Fischer et al. 2010

Hymenoptera
Trichogramma evanescens
body length: 0.3-0.4 mm

for comparision



Neuroptera
Chrysopa dorsalis
body length ~ 13 mm

Additional simplifications and reductions:

The tentorium is distinctly simplified in *C. pygmaea* as well as in Coleoptera (Polilov & Beutel 2009, 2010), Diptera (Schneeberg et al. 2013) and Phtiraptera (Tröster 1990). A complete reduction is documented for Strepsiptera (Beutel et al. 2005). The cell body size in the cortex layer of the brain reaches a lower limit at 2 µm in small insects as Strepsiptera, Coleoptera (Beutel et al. 2005) and Hymenoptera (Polilov 2012: Fig. 3H). In *C. pygmaea* this cell size does not go below this limit as well. Moreover simplifications in the circulatory and tracheal system occur in miniaturized insects which are correlated with the fact that diffusion is largely sufficient for the distribution of haemolymph and oxygen (*C. pygmaea*, Phtiraptera: Tröster 1990, Coleoptera: Polilov & Beutel 2009).

Conclusions

The lower size limit of many structures due to functional, physiological or physical constraints necessarily leads to a shortage of space in miniaturized forms. It is interesting that in all studied insect orders this problem is consistently resolved through convergent structural modifications and never by reducing the overall complexity of the head.

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