Evolution of moths and butterflies – the challenges of gathering reliable evidence from a poor fossil record

Maria Heikkilä
Peter Buck postdoctoral fellow
Smithsonian Institution NMNH
Department of Paleobiology and Department of Entomology
Lepidoptera – Moths and Butterflies

- over 157,000 described species
- largest single radiation of plant-feeding insects
- scales on wings and body
Lepidoptera (lepis = scaly; ptera = wing)

https://thebutterflydiaries.wordpress.com/category/learning-about-lepidoptera/
Evolutionary history of moths and butterflies

• A robust phylogenetic framework has recently begun to emerge

Regier et al. 2013
Evolutionary history of moths and butterflies

- When and under what paleoecological circumstances did major groups diversify?
- Why have some groups been so successful?
- When did structural and behavioral novelties arise?
- Divergence time analyses (genetic data + morphological data + fossil data)
The molecular clock

http://www.evolution.berkeley.edu/evosite/evo101/IIE1cMolecularclocks.shtml
Fossils as calibration points

Doorenweerd et al., 2016
Fossil record of moths and butterflies is poor

- References to 4,568 fossil specimens
- Only 985 fossil specimens placed in taxonomic groups
- Identifications often based on superficial similarity to extant species, not apomorphies

Sohn, Labandeira, Davis & Mitter, 2012
Fossil Lepidoptera
Lepidopteran Fossil Record: Overview

Sohn et al. 2015

**Diagram A:**
- **Amber/Copal:** 40%
- **Compression/Impression:** 52%
- **Silica/Permineralization:** 1%
- **Sieved residue:** 7%
- **Other preservation types:** >1%

**Diagram B:**
- **Leaf mines:**
- **Other feeding damage:**
- **Larval cases:**
- **Larval frass:**

- **Silica/Permineralization**
- **Salt Deposit**
- **Peat/Lignite**
- **Amber/Copal**
- **Compression/Impression**

**Legend:**
- **Yellow**
- **Gray**
- **Red**
- **Orange**
- **Green**
Taphonomy of Lepidoptera

Fast decay in water (Duncan, 1997)
Scales cover much of diagnostic characters
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CI: compression/impression
T: trace fossils
AM: amber
CO: copal
SI: silica
SR: sieved residues
GC: gut contents and coprolites
AS: asphaltum & tar sands
PE: peat or lignites

Identifications re-examined by international network of experts

Reliable fossils to be used in divergence time analysis

Sohn et al. 2015
Trichoptera – Caddisflies
ca. 12,000 described species

Fossils interpreted as caddisfly larval cases
Early Permian (299 – 284 Ma)
Mouro et al. 2016

Amphiesmenoptera

Oldest moth fossil
Early Jurassic (ca. 190 Ma)

Fossilized scales
Triassic – Jurassic (ca. 201 Ma)

Lepidoptera – Moths and Butterflies
>150,000 described species
Lepidoptera

- *Archaeolepis mane* Whalley, 1985
  188.1 Ma - 195 Ma Dorset, England
  BMNH, London
Lepidoptera

- Fossilized scales from a core drilled in Northern Germany Triassic - Jurassic sediments, 201 Ma

v. Eldijk et al. *in prep.*
Late Middle Jurassic (ca. 165 Ma)
Jiulongshan Formation in Northeastern China

Mesokristensenia sinica Huang, Nel & Minet 2010
Micropterigidae

- *Parasabatinca aftimacrai* Whalley, 1978
Lebanese amber
Grès de Basa Fm. 130±1.5 - 125±1.0 Ma
Natural History Museum of the Lebanese University
Glossata

*Protolepis cuprealata* Kozlov, 1989
Karabastau Formation, Kazakhstan
Late Jurassic (161-151 Ma),
PIRAS, Moscow
Glossata

Glossatan larva in Lebanese amber
Grès de Basa Fm. or lateral equivalents
130±1.5 - 125±1.0 Ma
Natural History Museum of the Lebanese University
Burmese (ca. 99 Ma) and New Jersey Amber (90 Ma)
Revised checklist of pygmy moth fossils (Nepticulidae)

Camiel Doorenweerd et al. 2015
Naturalis Biodiversity Center
Leiden, The Netherlands
Review of fossil butterflies (Papilionoidea) in peer review

Vanessa amerindica
Miller and Brown, 1989

Oligodonta florissantensis
Brown, 1976

Voltinia dramba
Hall, Robbins & Harvey 2004

http://www.nature.com/nature/journal/v428/n6982/fig_tab/428477a_F1.html

Rienk de Jong
Naturalis Biodiversity Center
Leiden, The Netherlands
Earliest evidence of butterflies, 55 Ma

- *Protocoeliades kristensenii*
  Jong, 2016
Fur Formation, 55 Ma, Denmark

Thomas Simonsen
Natural History Museum Aarhus
Denmark
Fossil tortrix and leafroller moths (Tortricoidae)

- 82 specimens, 60 missing
- In most cases the subfamily/tribe cannot be determined
- Most are too recent for calibration purposes
Fossil silk, emperor and sphinx moths (Bombycoidea)

- 53 fossils
- 37 are fossilized cocoons
- Relatively recent, many too young to be used as calibration points
Conclusions

• Known fossil Lepidoptera re-examined by international network of experts

• Preliminary results show that identifications often unsupported

• Encourage future workers to follow best practices
  • describing fossils
  • selecting calibration points
Thank you!

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Societas Entomologica Fennica, Finland

a.a.maria.heikkila@gmail.com / heikkilam@si.edu