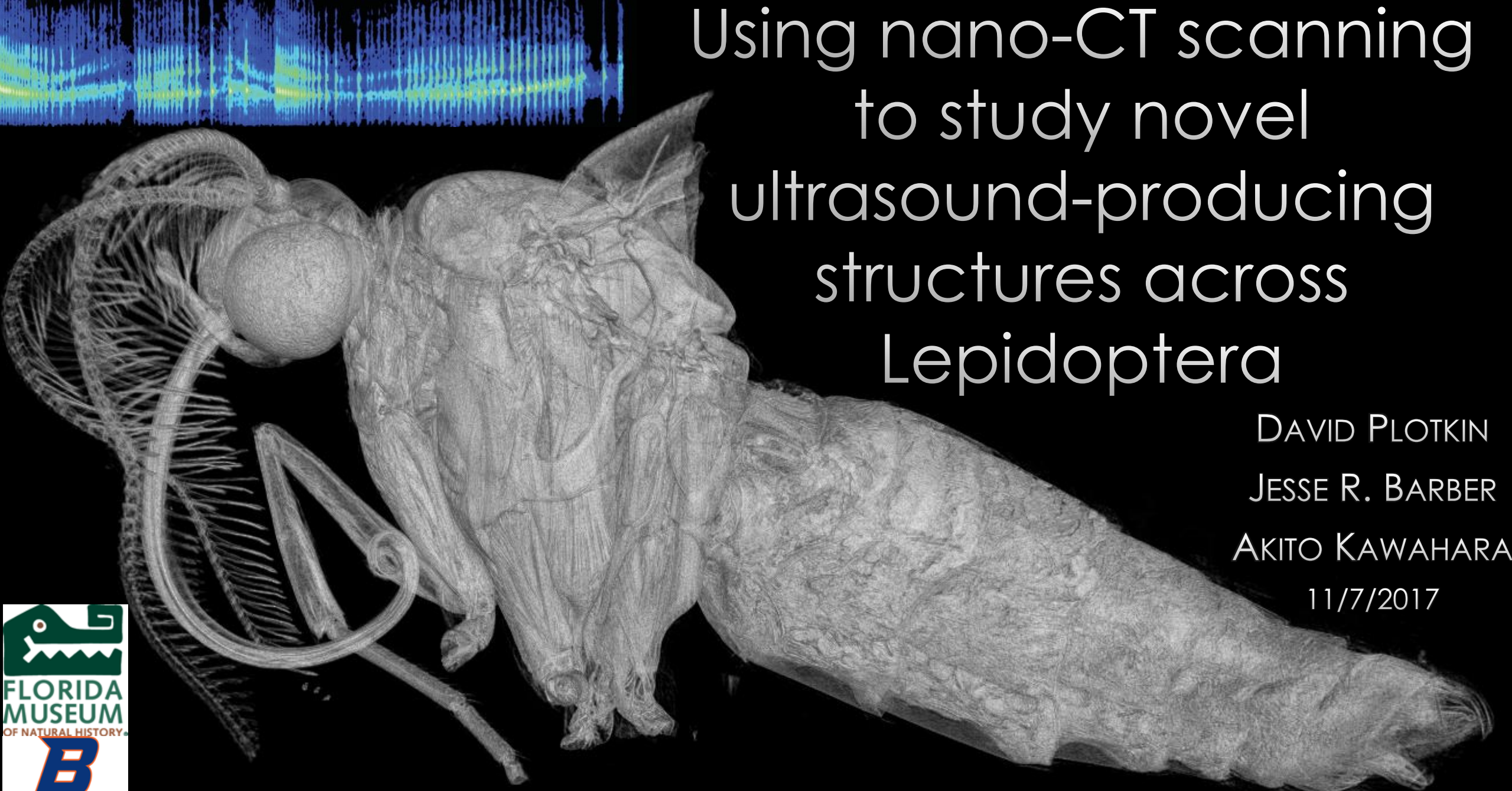
Using nano-CT scanning to study novel ultrasound-producing structures across Lepidoptera

David Plotkin

Jesse R. Barber

Akito Kawahara

11/7/2017

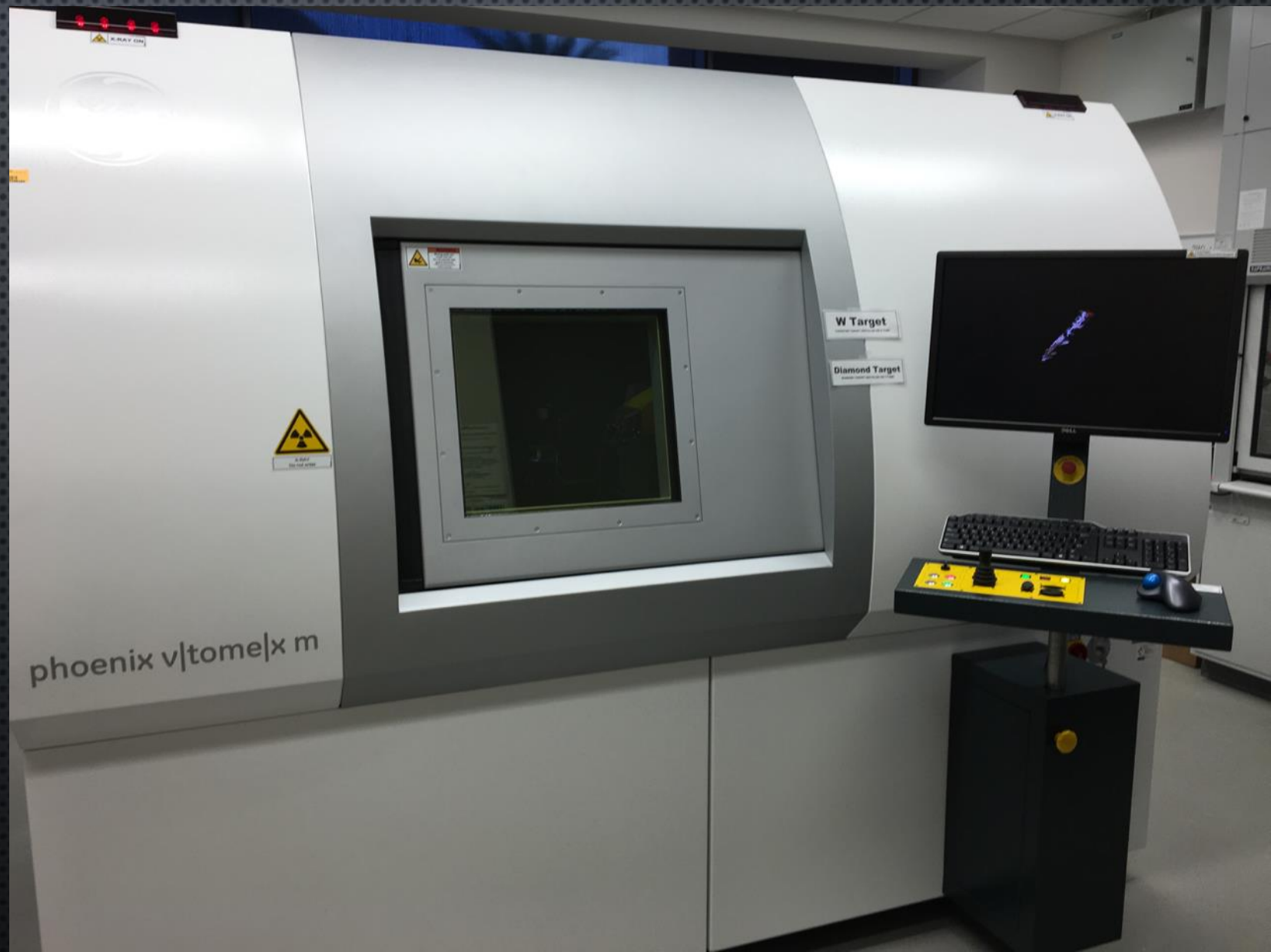


FLORIDA MUSEUM OF NATURAL HISTORY

BOISE STATE UNIVERSITY

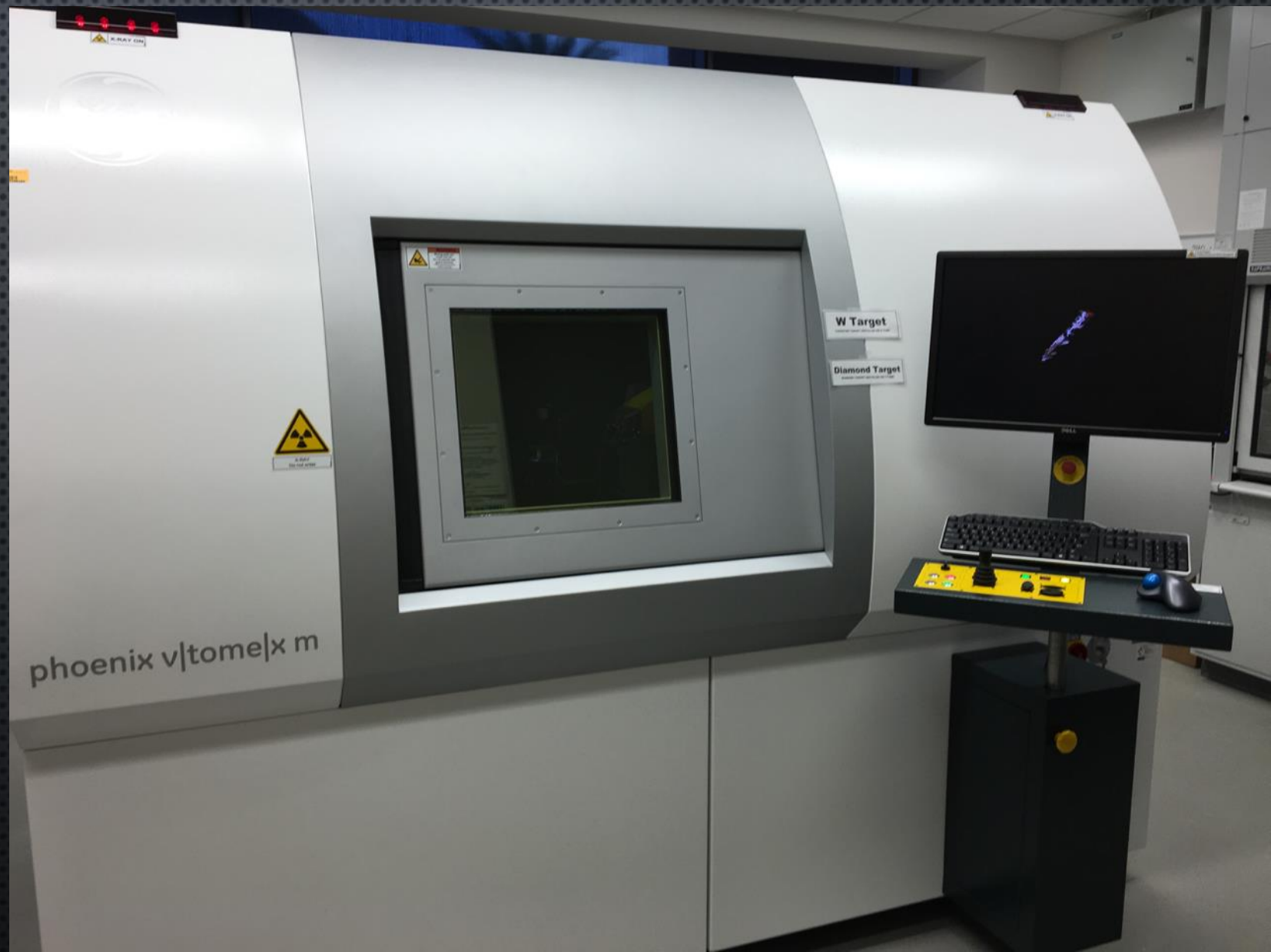
Nano-computed Tomography (nano-CT)

- Higher-resolution version of micro-CT



Nano-computed Tomography (nano-CT)

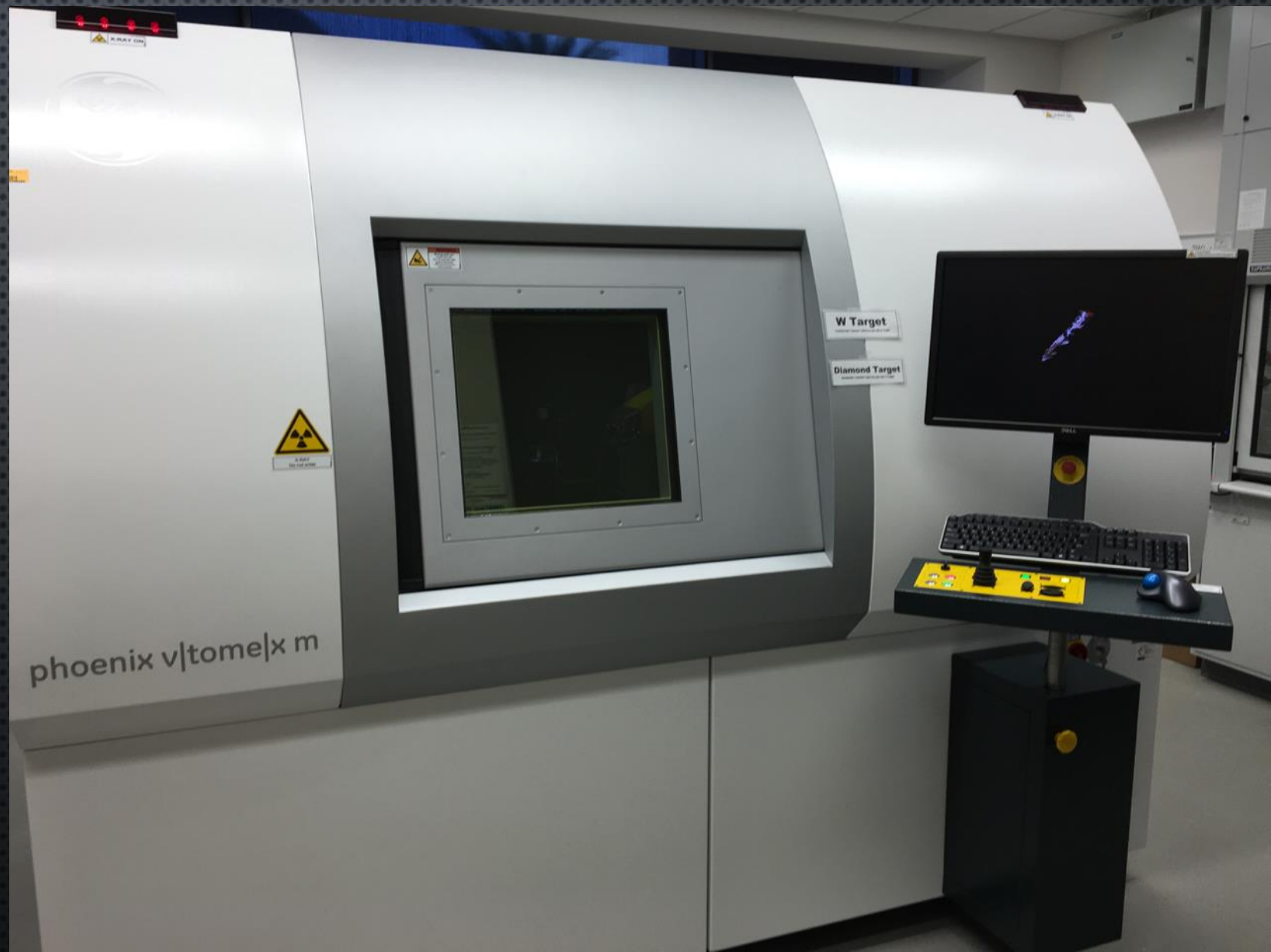
- Higher-resolution version of micro-CT
- Higher-resolution version of regular CT



Nano-computed Tomography (nano-CT)

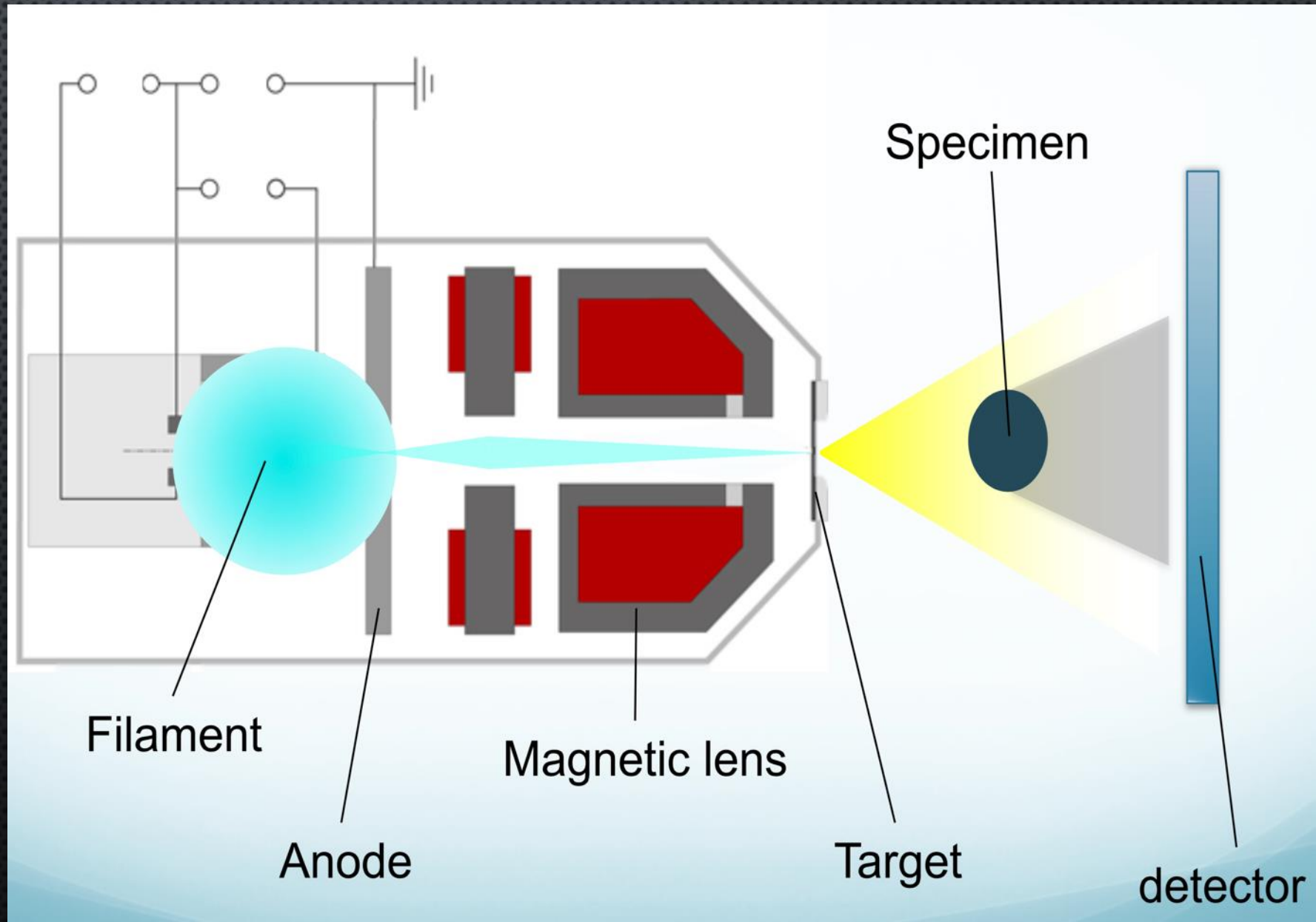
- Higher-resolution version of micro-CT
- Higher-resolution version of regular CT

- Non-invasive scanning of museum specimens, to create 3D model with pixel dimensions < 1 µm

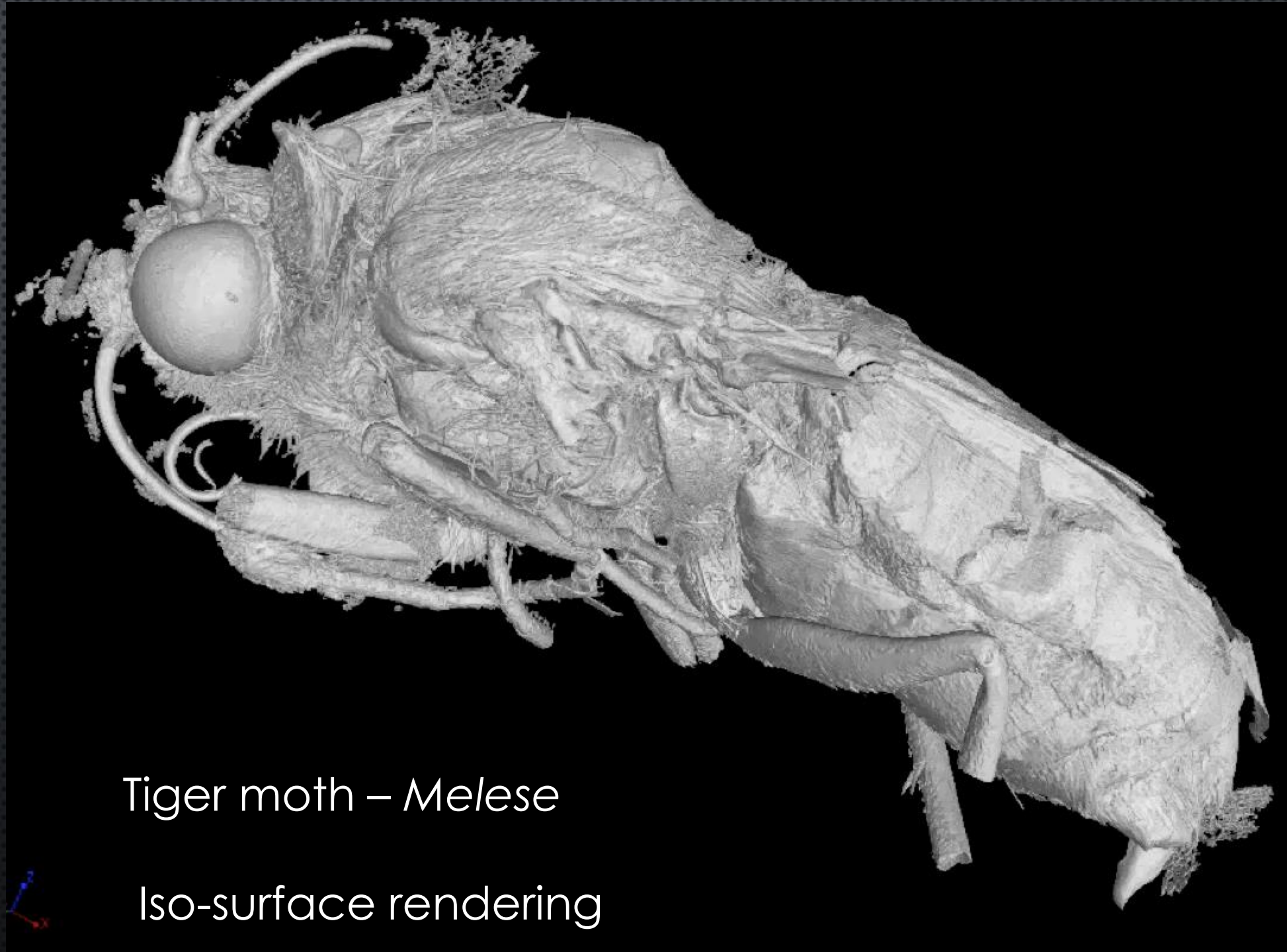


Nano-computed Tomography (nano-CT)

- X-rays transmitted through a specimen
- Detector records x-rays that are not absorbed
- Software converts data to pixels
- More software creates a 2D cross section
- Rotate and repeat

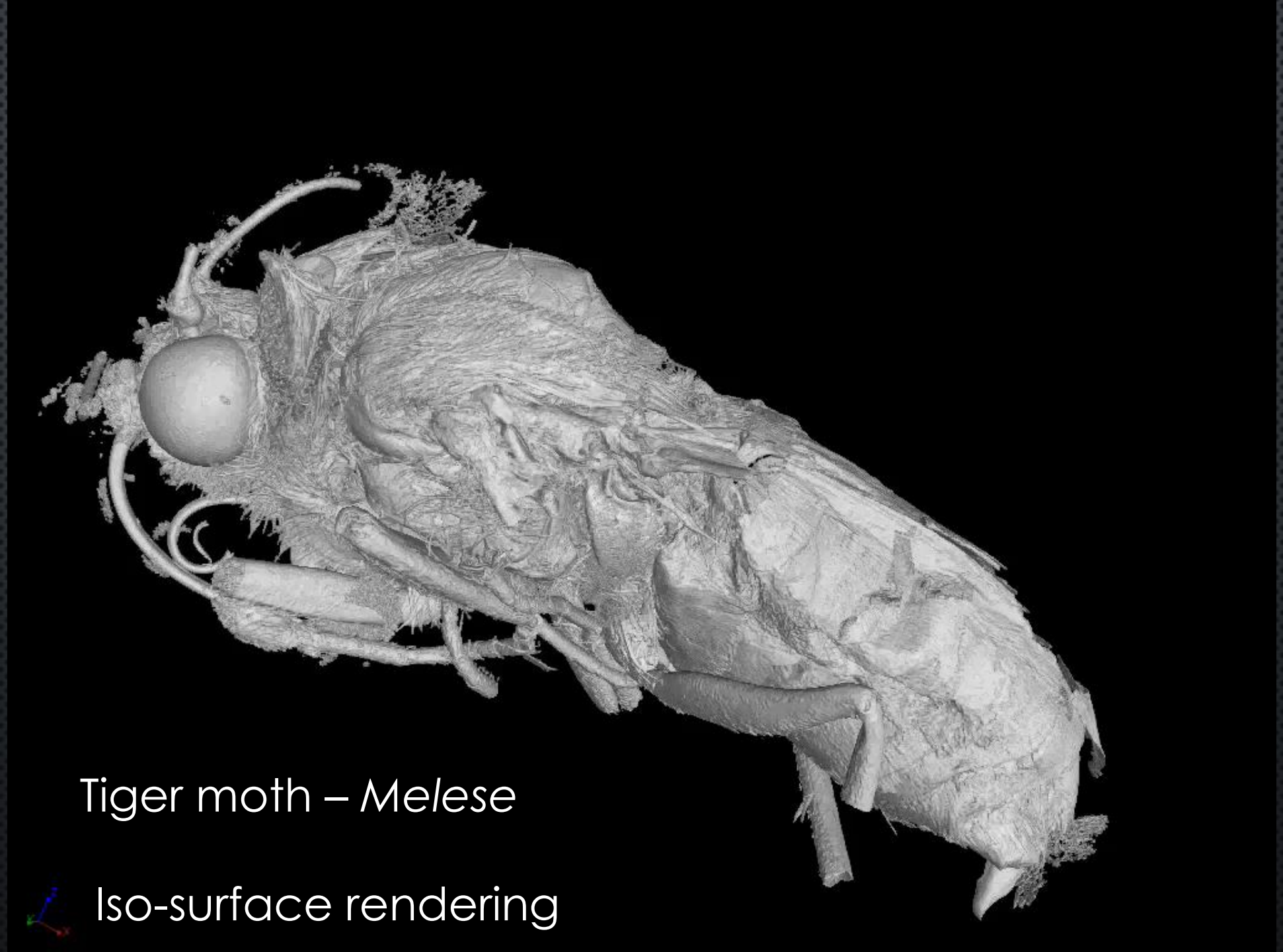


- Assemble the 2D slices and convert into a 3D reconstruction
- Can selectively exclude certain body parts in order to view internal/obscured structures



Tiger moth – *Melese*

Iso-surface rendering



Tiger moth – *Melese*

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Systematic Entomology

Systematic Entomology (2014), **39**, 606–618 DOI: 10.1111/syen.12067

METHODS

Virtual dissections through micro-CT scanning: a method for non-destructive genitalia 'dissections' of valuable Lepidoptera material

THOMAS J. SIMONSEN and IAN J. KITCHING

Department of Life Sciences, Natural History Museum, London, U.K.

Abstract. Since its first application to the field more than 10 years ago, micro-computed tomography (micro-CT) has been a state-of-the-art technology in the study of insect morphology and anatomy. Despite showing great potential for various types of non-destructive 'dissections', the method has, however, seen very limited use in

Diagnostic structures *in situ*

Accurate measurements

Type specimens

Really small specimens

Systematic Entomology

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METHODS

Virtual dissections through micro-CT scanning: a method for non-destructive genitalia 'dissections' of valuable Lepidoptera material

Diagnostic structures *in situ*

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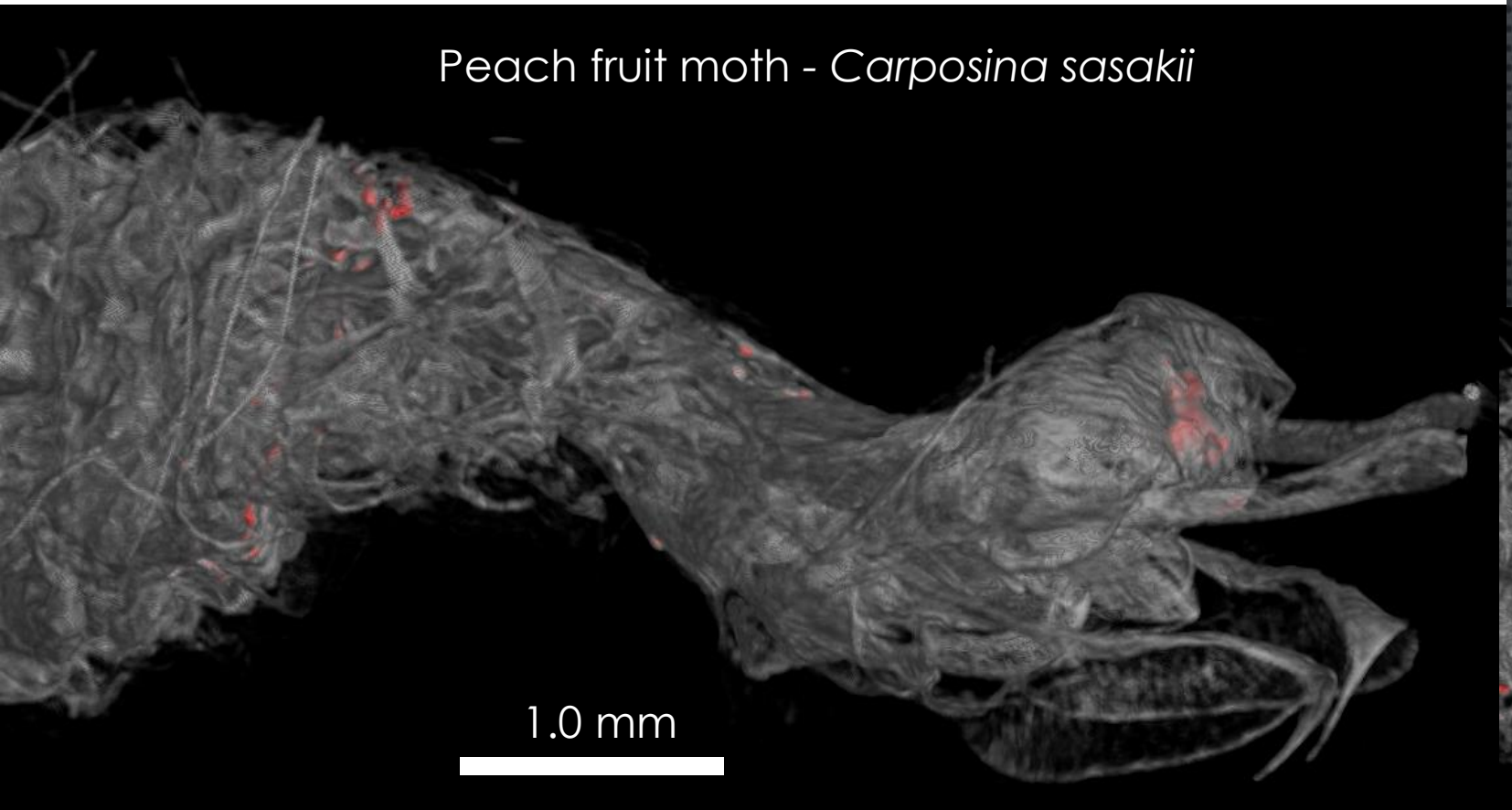
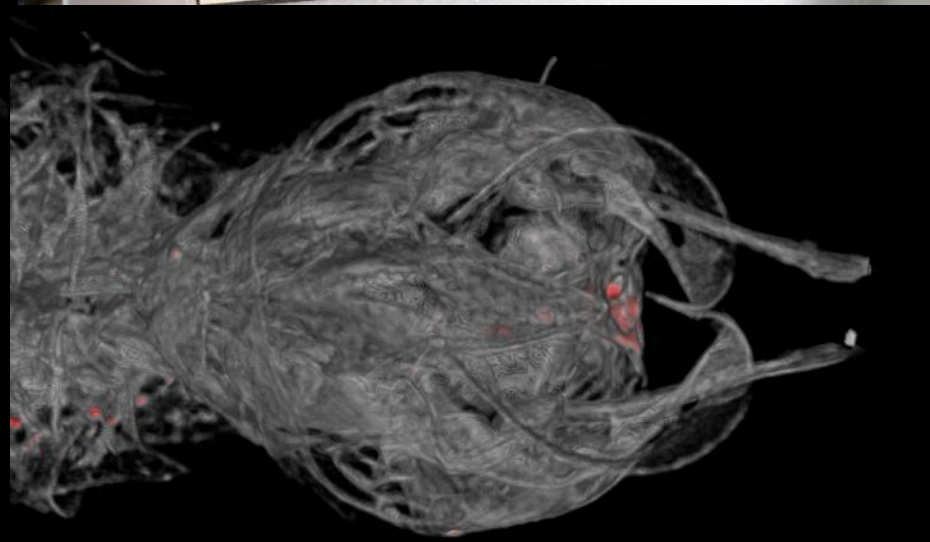
Peach fruit moth - *Carposina sasakii*

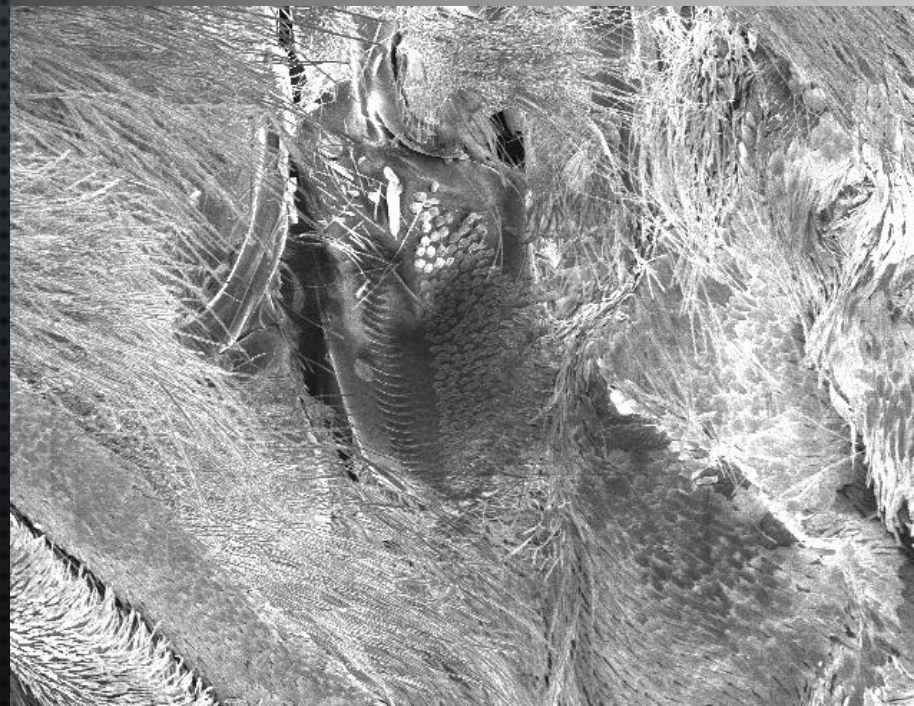




Identifying new sound-producing structures

- Field observations
- Electron microscopy

- Can nano-CT scanning also help locate these structures?



"The bat–moth arms race has existed for over 60 million years…"
(Kawahara & Barber, 2015)

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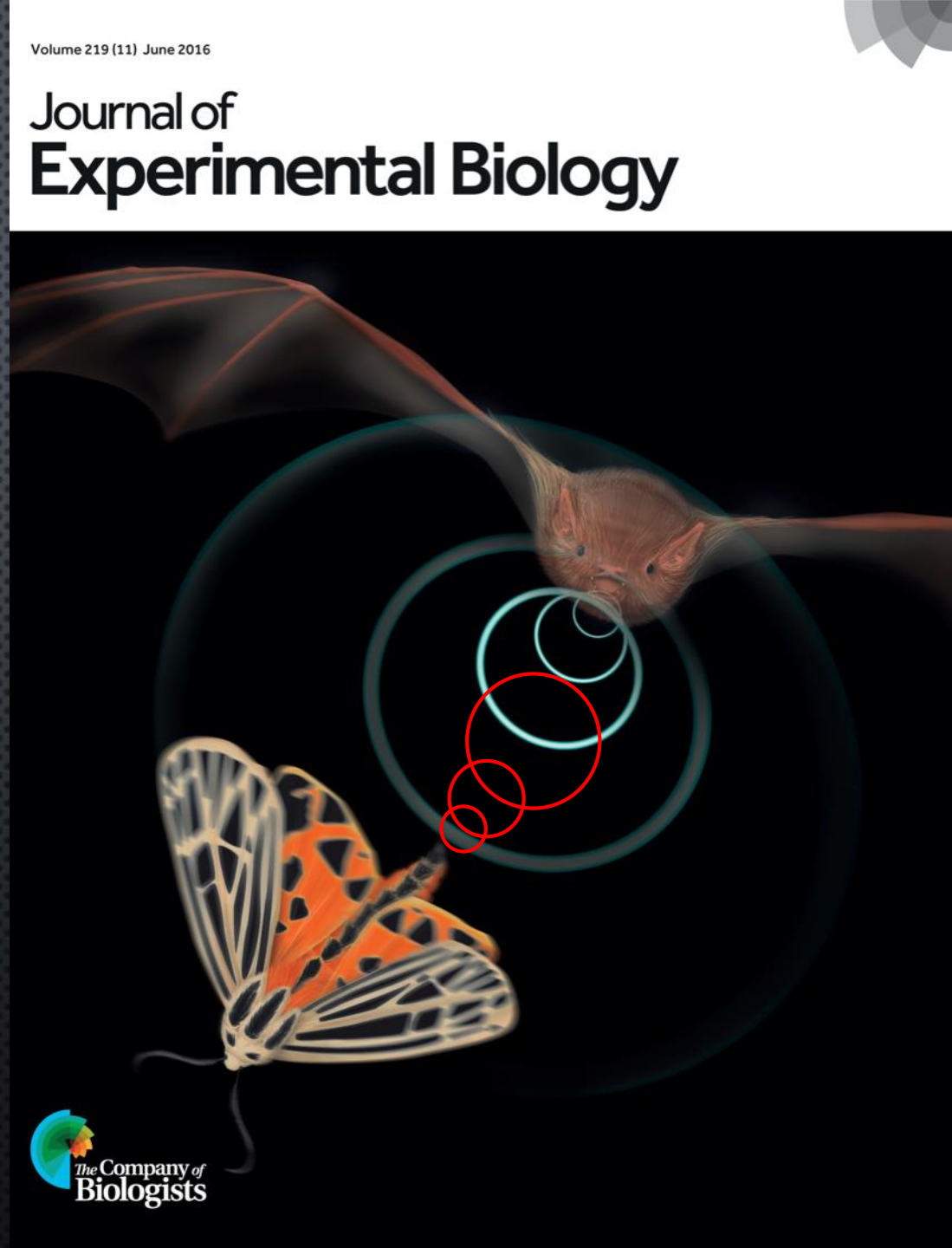

"The bat–moth arms race has existed for over 60 million years…"
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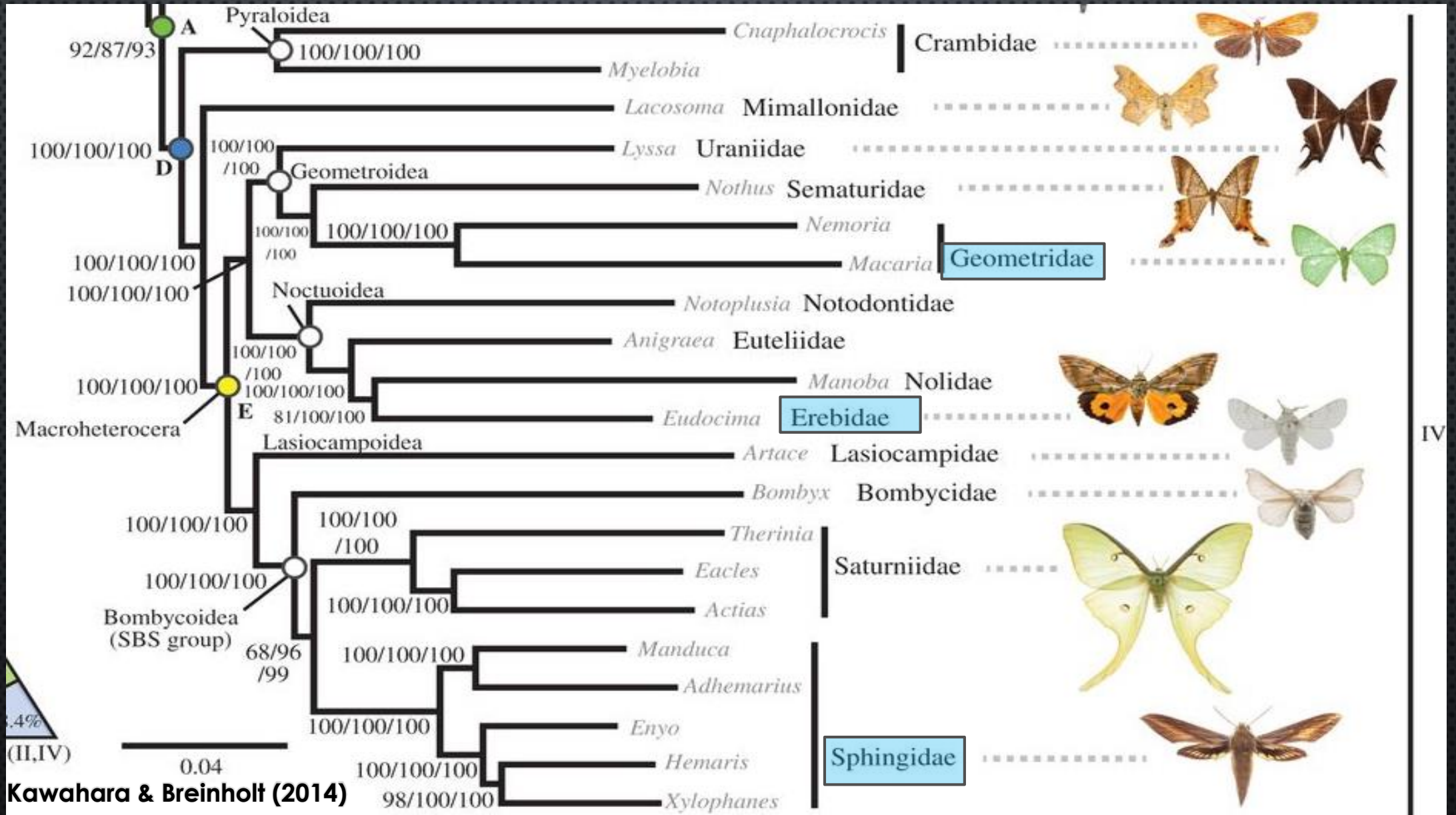
DoodleBug Biology (@DoodleBugBio)

Volume 219 (11) June 2016

Journal of Experimental Biology

The Company of Biologists

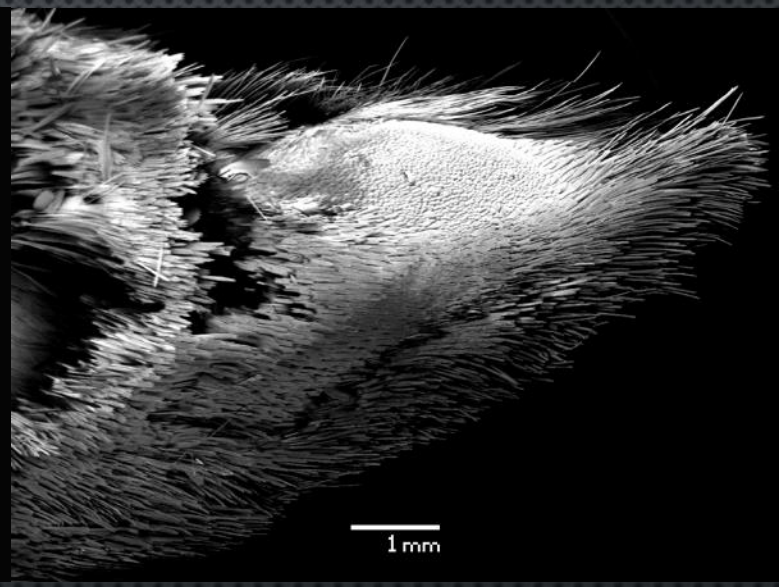
Evolution of defensive ultrasound production in moths



Kawahara & Breinholt (2014)

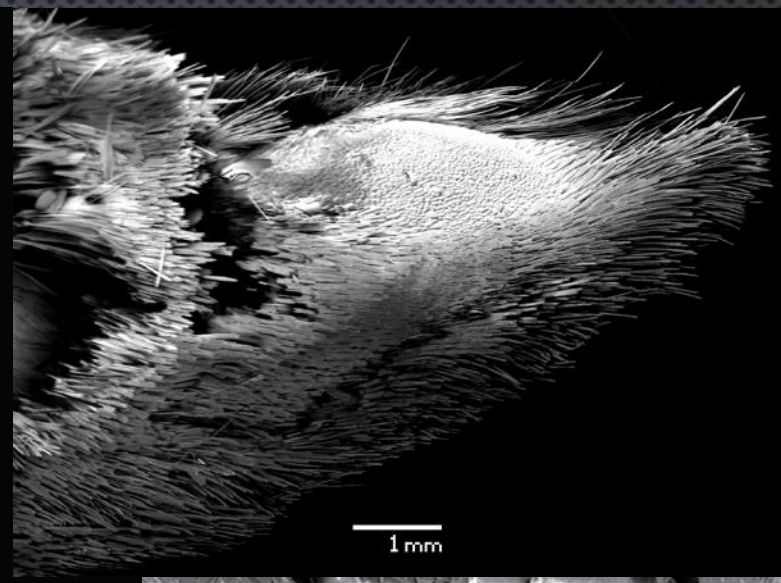
Evolution of defensive ultrasound production in moths

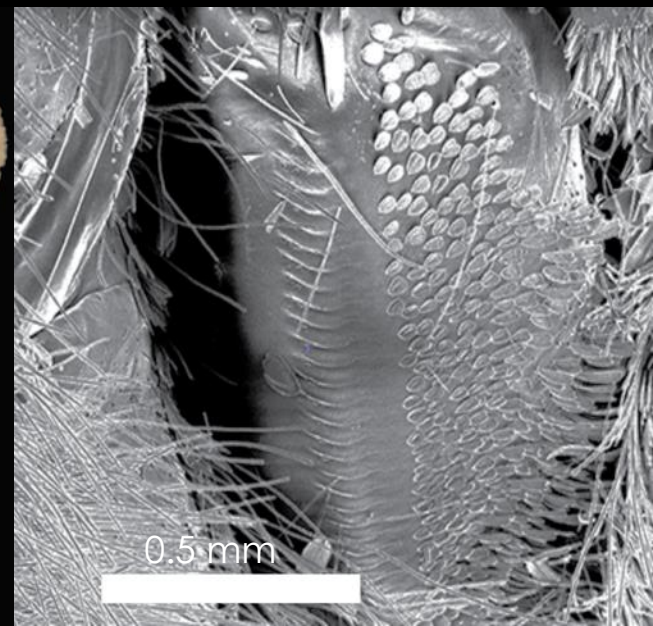
- Sphingidae – abdominal scales



Evolution of defensive ultrasound production in moths

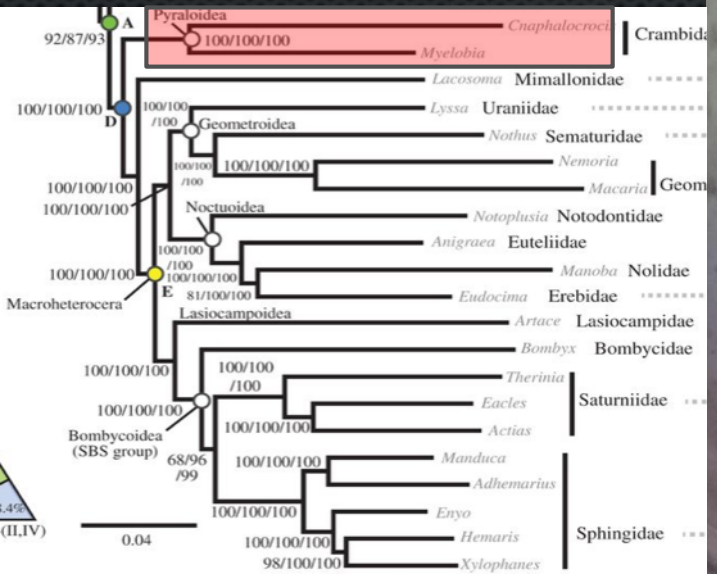
- Sphingidae – abdominal scales
- Erebidae: Arctiinae – thoracic tymbals





Identifying new sound-producing structures

Pyralidae/Crambidae– dorsal thoracic scales



Axel Hausmann, SNSB (2010)

Barber et al. (in prep.)

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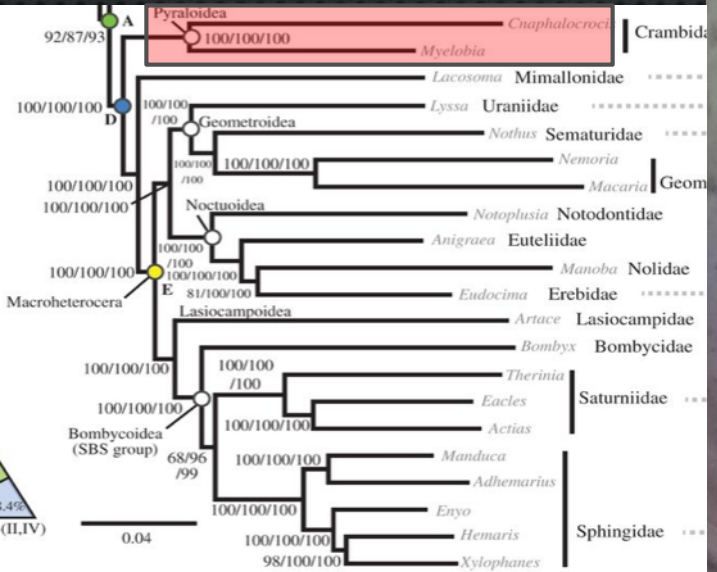
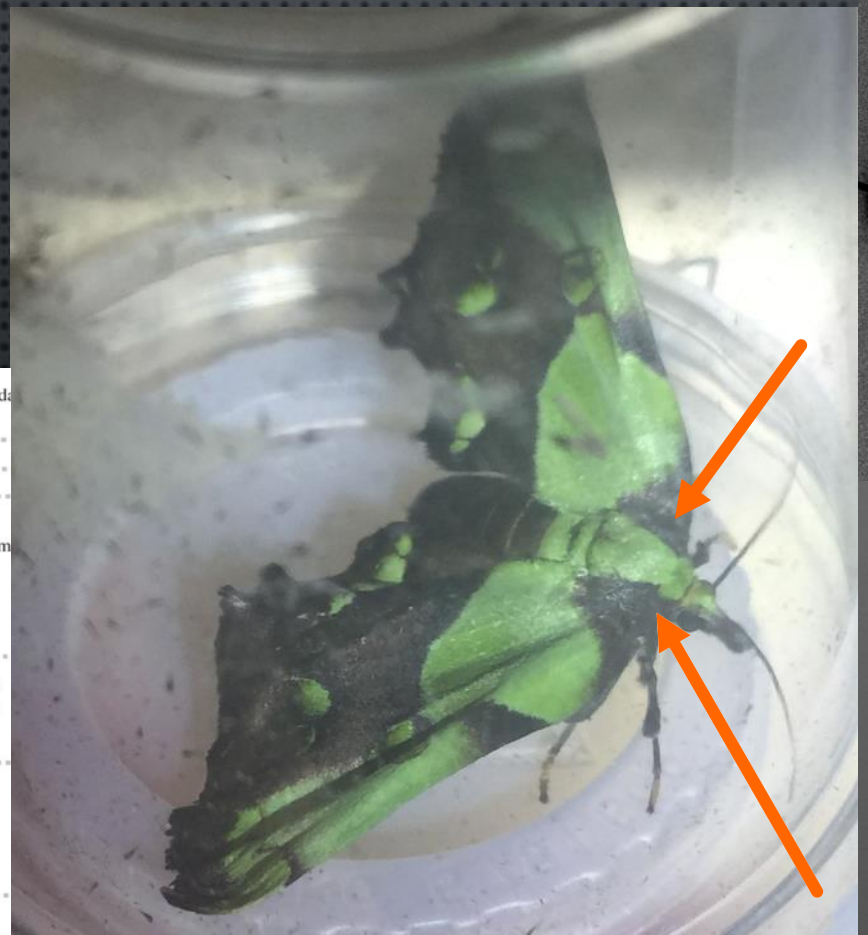
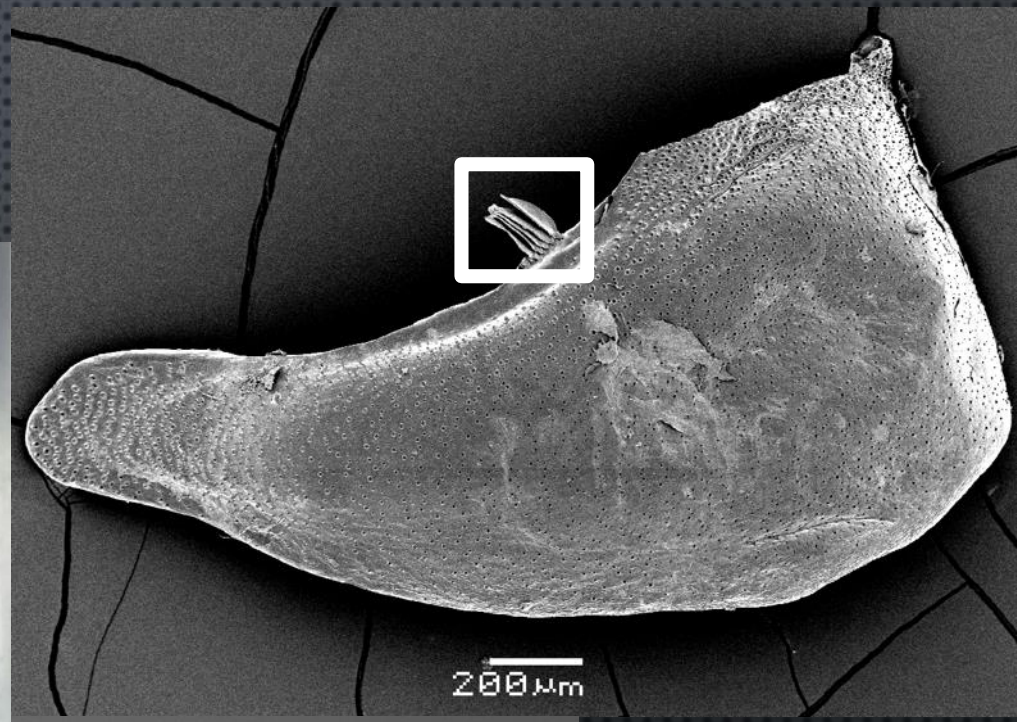
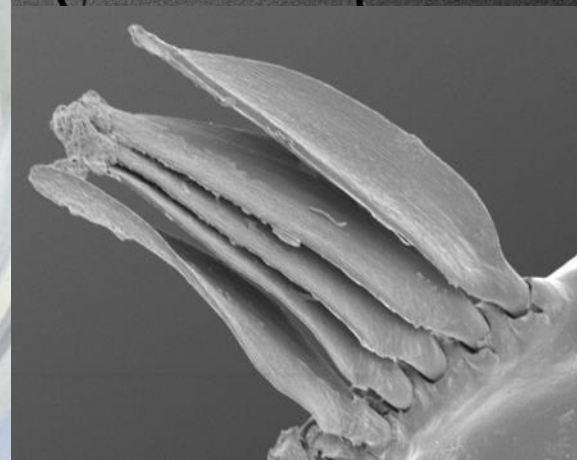




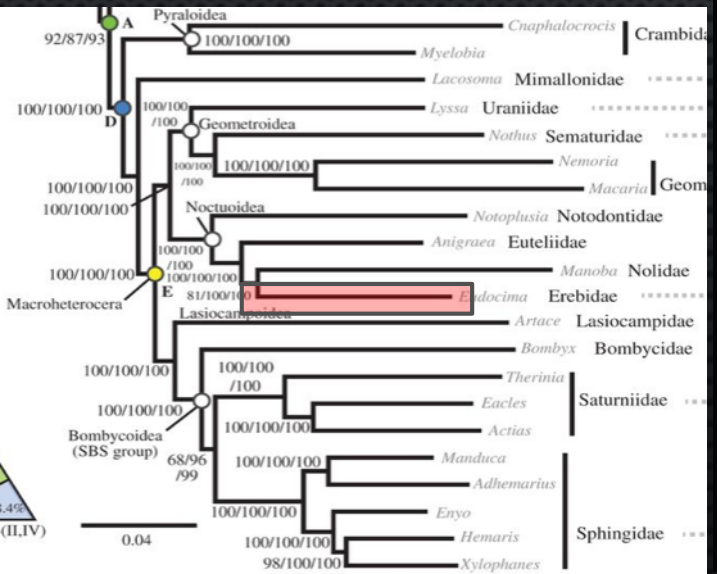


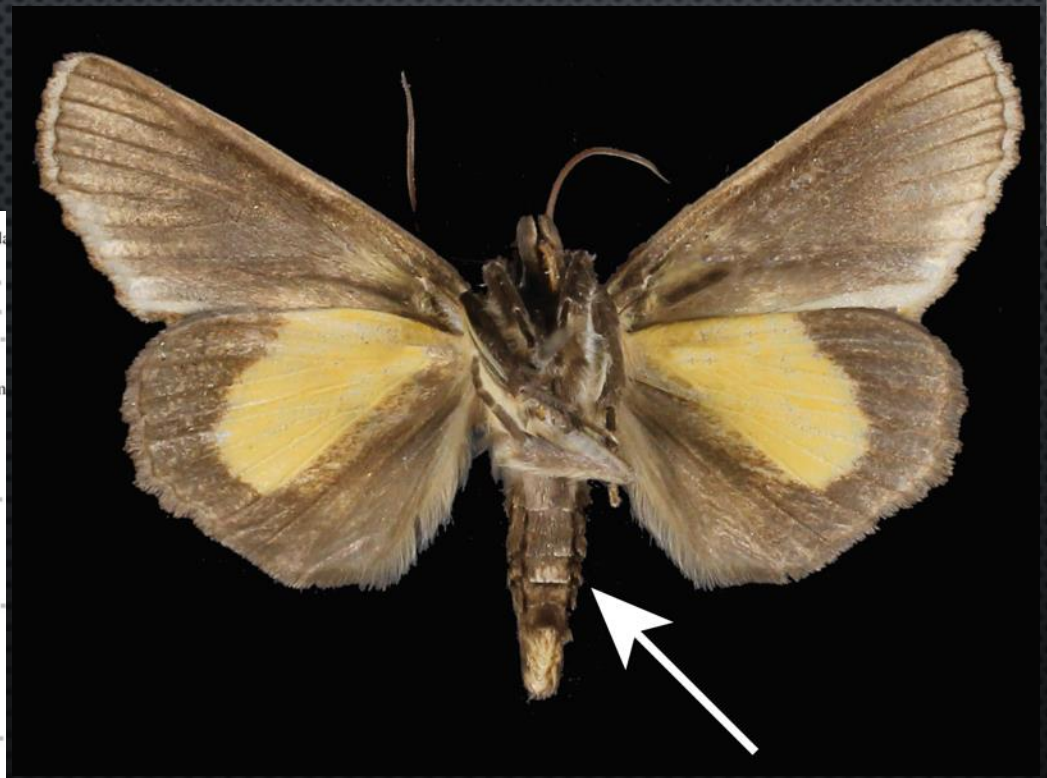


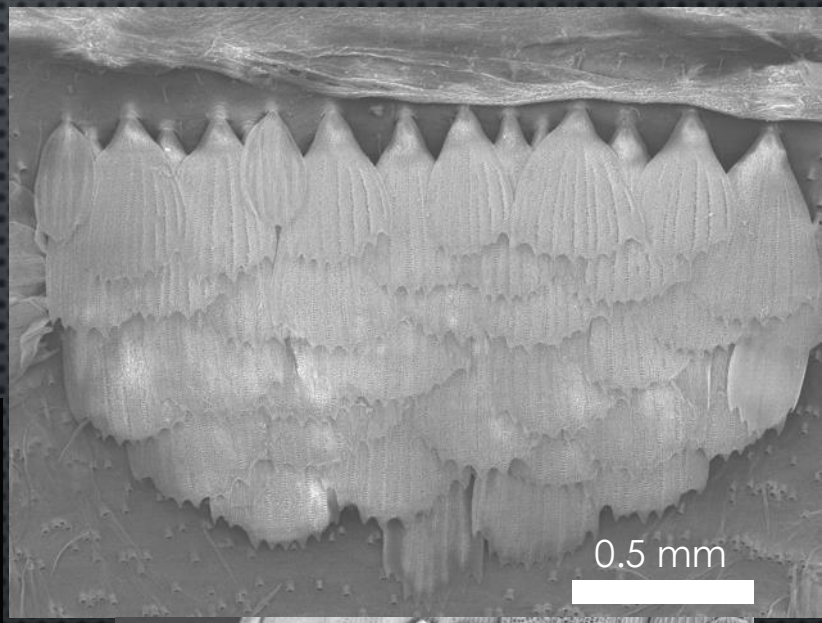
Barber et al. (in prep.)

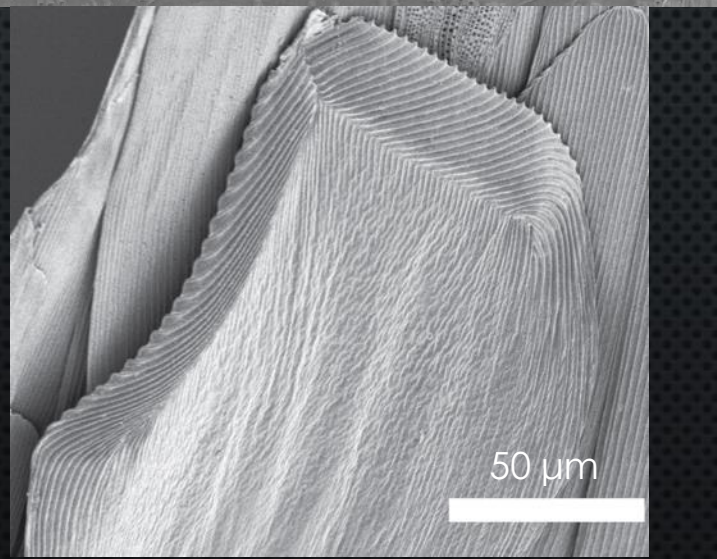
Identifying new sound-producing structures

Erebidae: Calpinae – ventral abdominal scales









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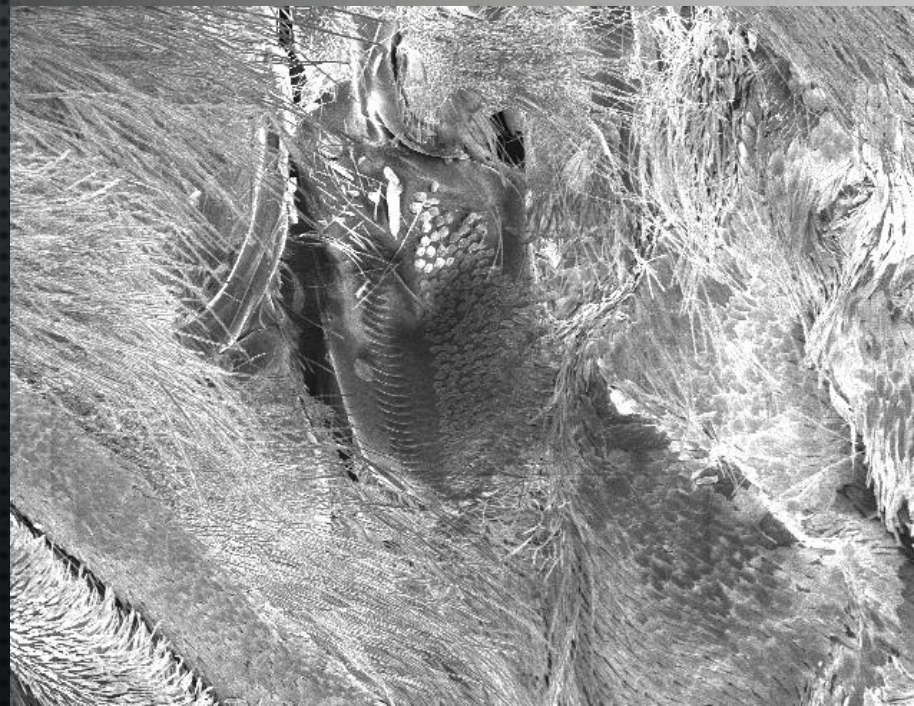

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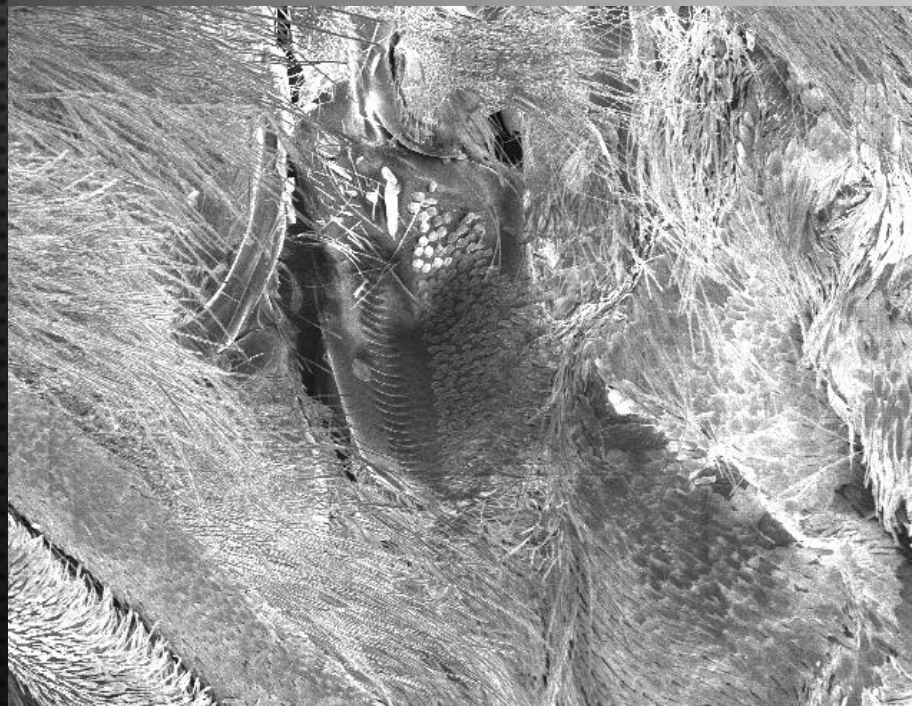
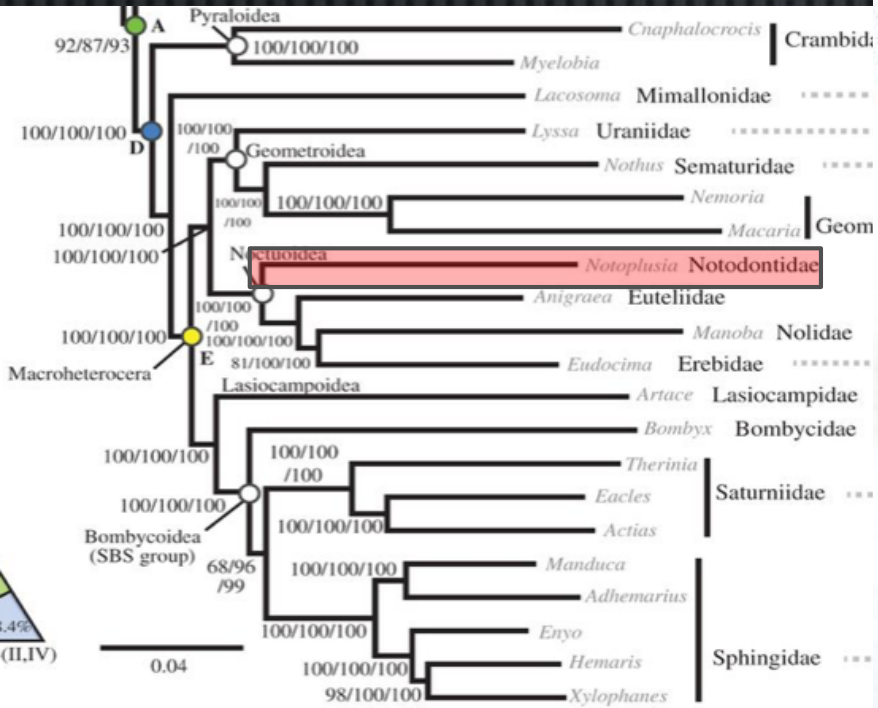
MAYBE!!!

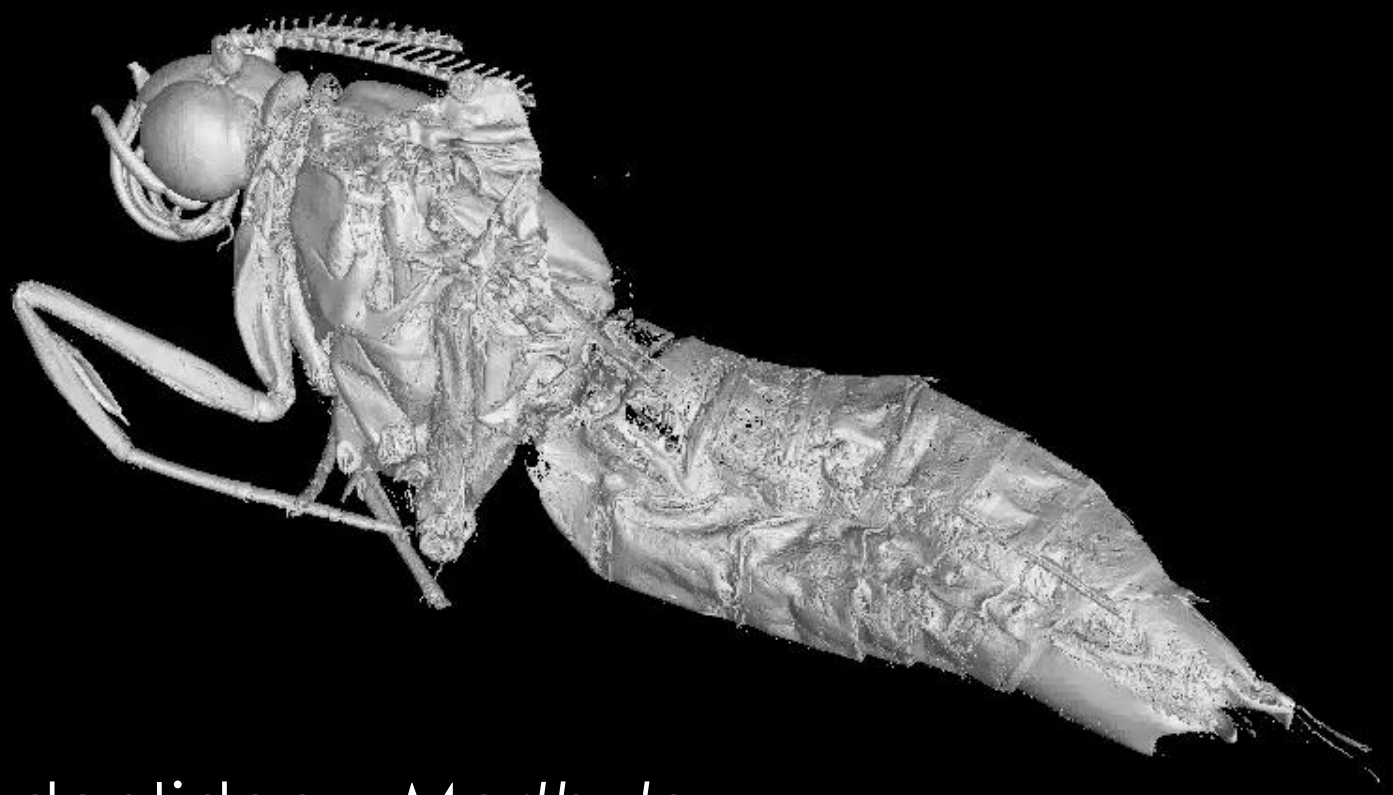


Marthula (Noctuoidea: Notodontidae)

Abdomen moves during ultrasound production, but no correlated structures observed with regular microscopy or SEM

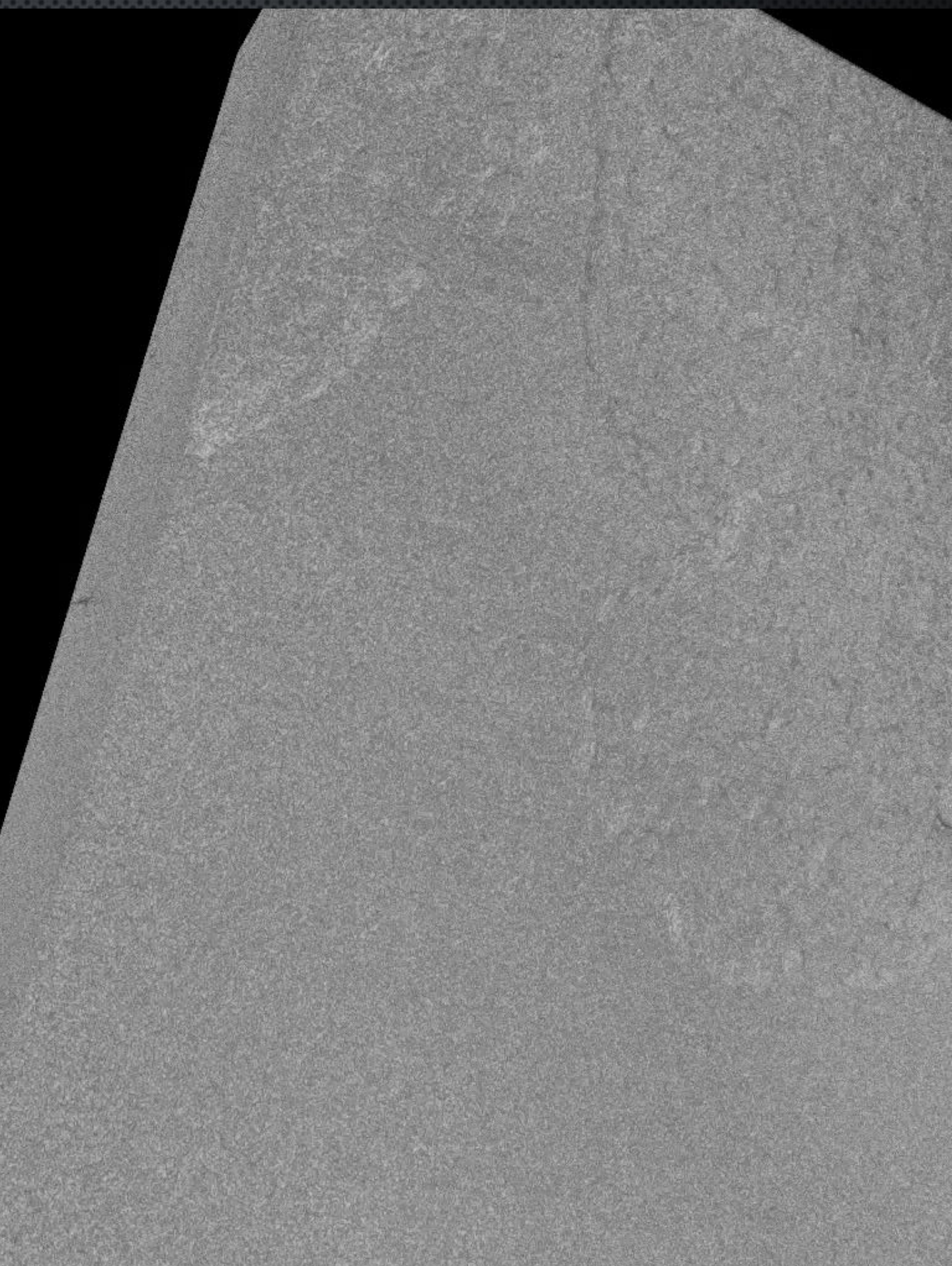


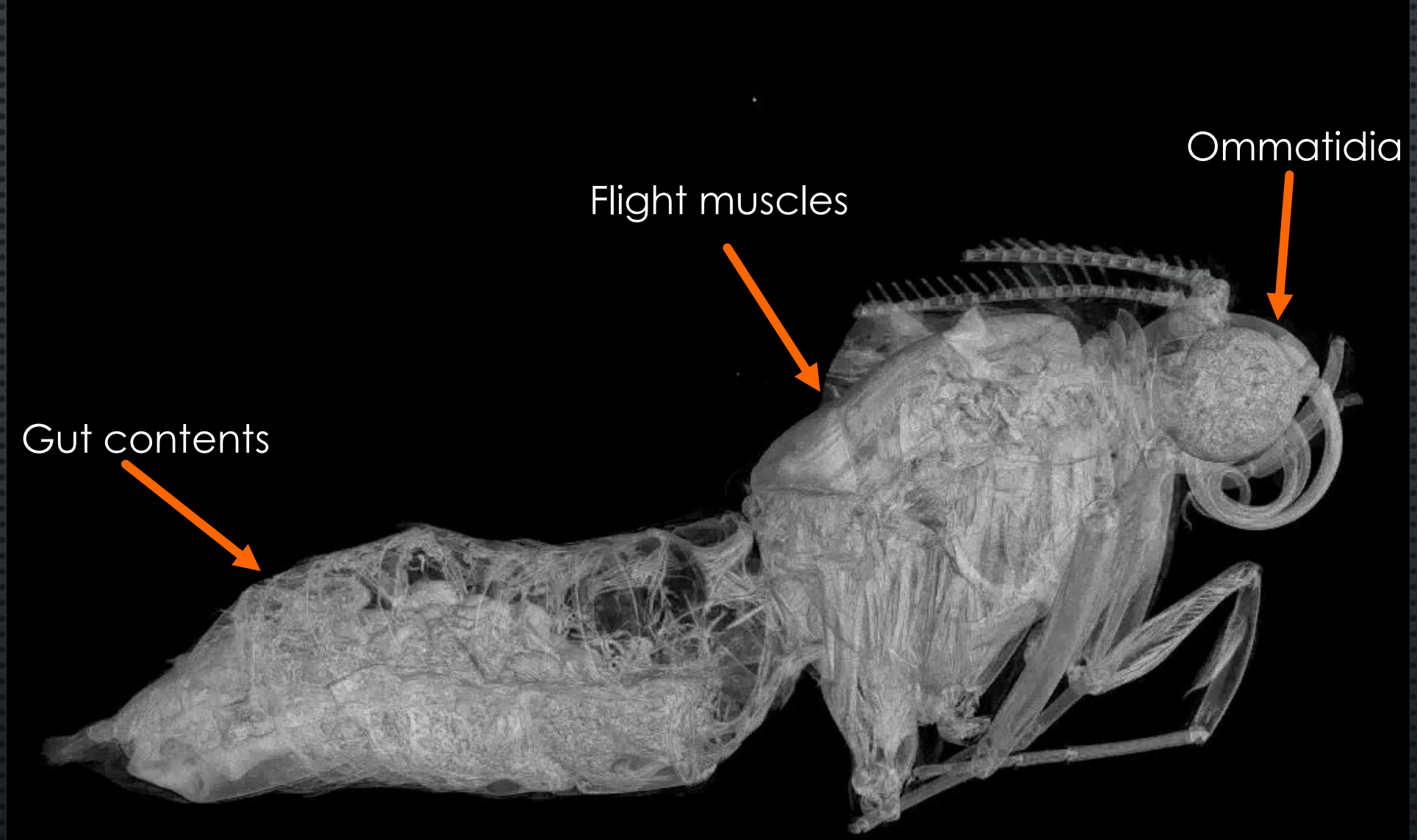
Dan Janzen (2008)



Notodontidae – *Marthula*

Iso-surface rendering





Notodontidae – *Marthula*

Volumetric rendering

Search for less dense cuticle – possible evidence of ultrasound production

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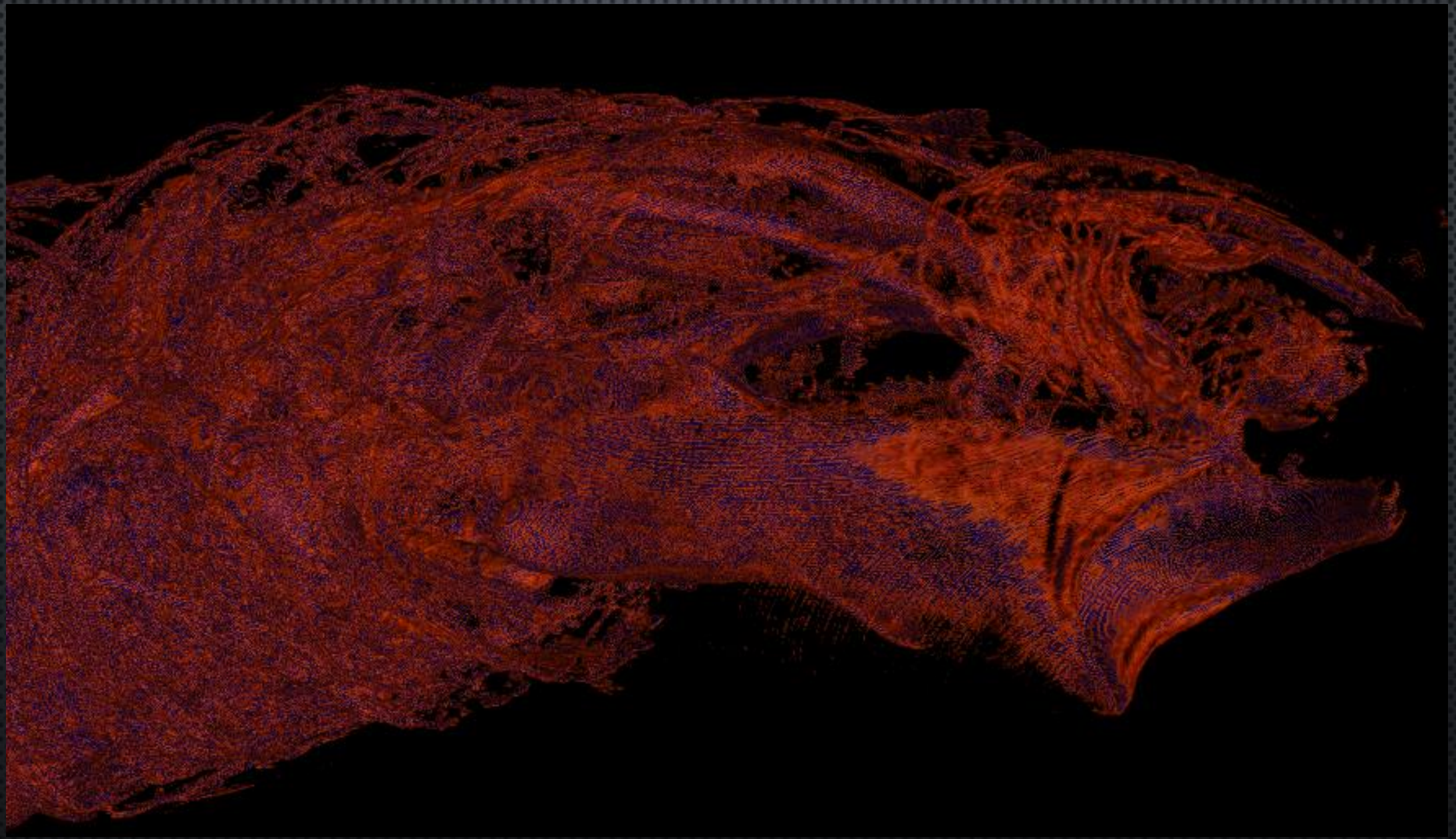
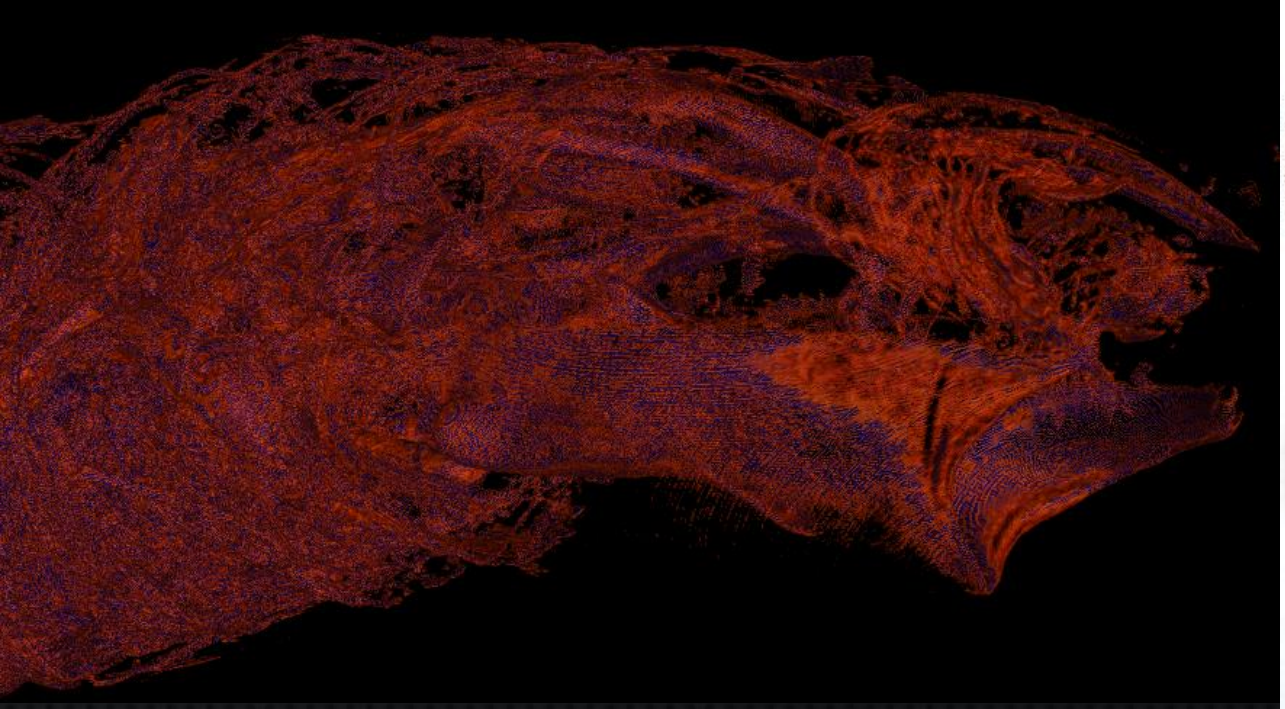
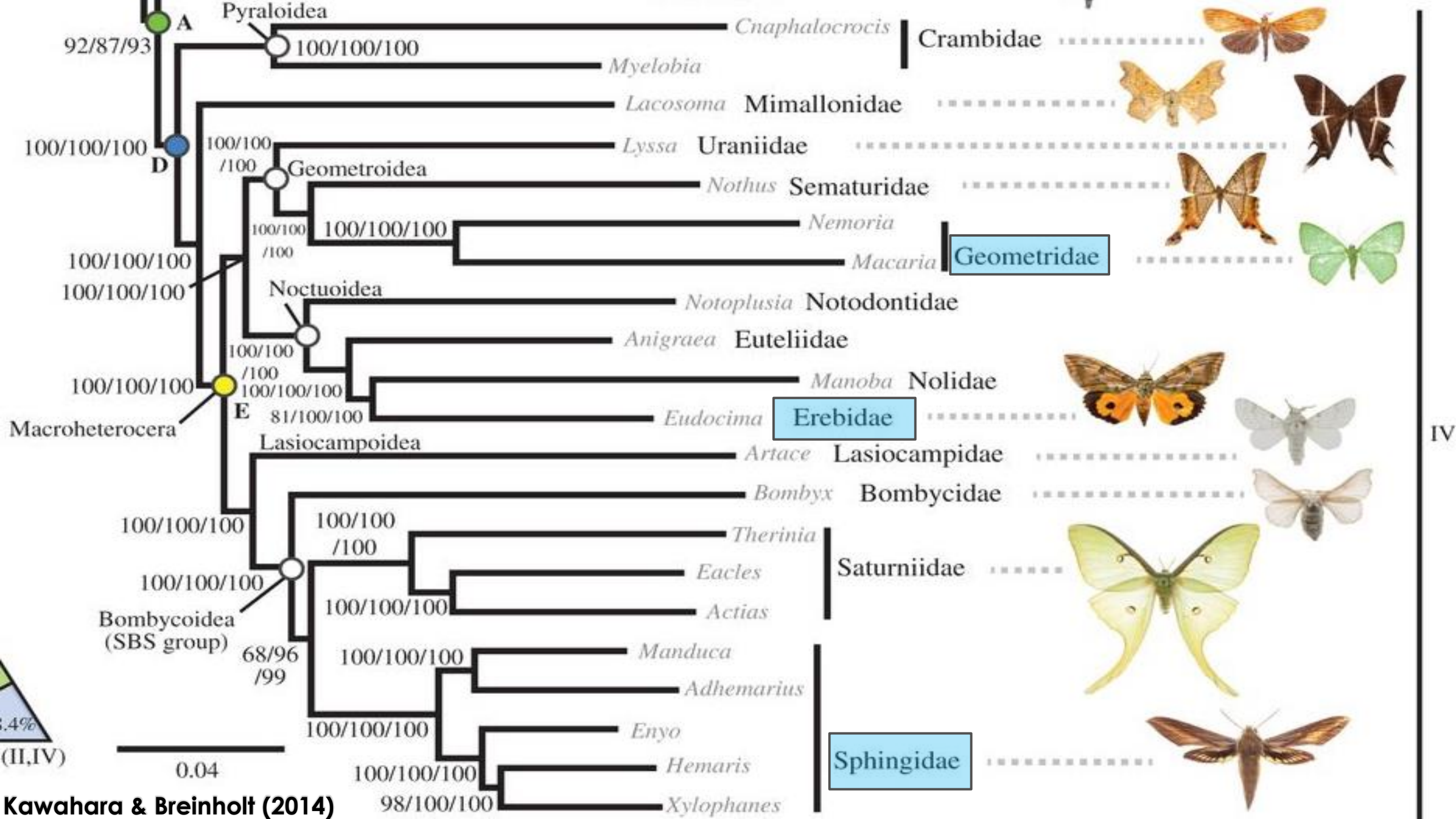




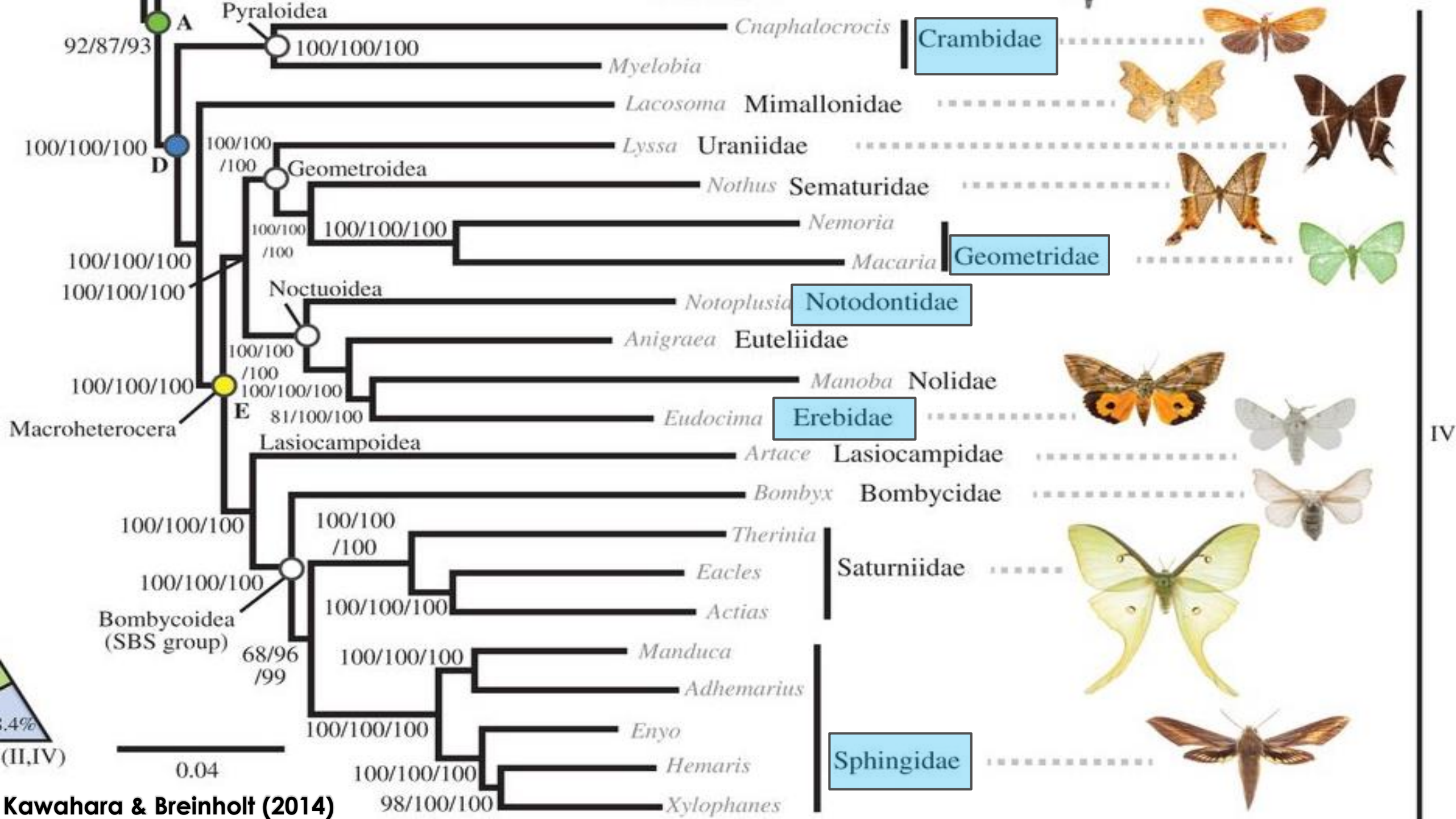
Nano-CT offers new avenues for exploring insect biodiversity and morphological variation

Useful tool for developing new hypotheses

Dan Janzen (2008)



Kawahara & Breinholt (2014)



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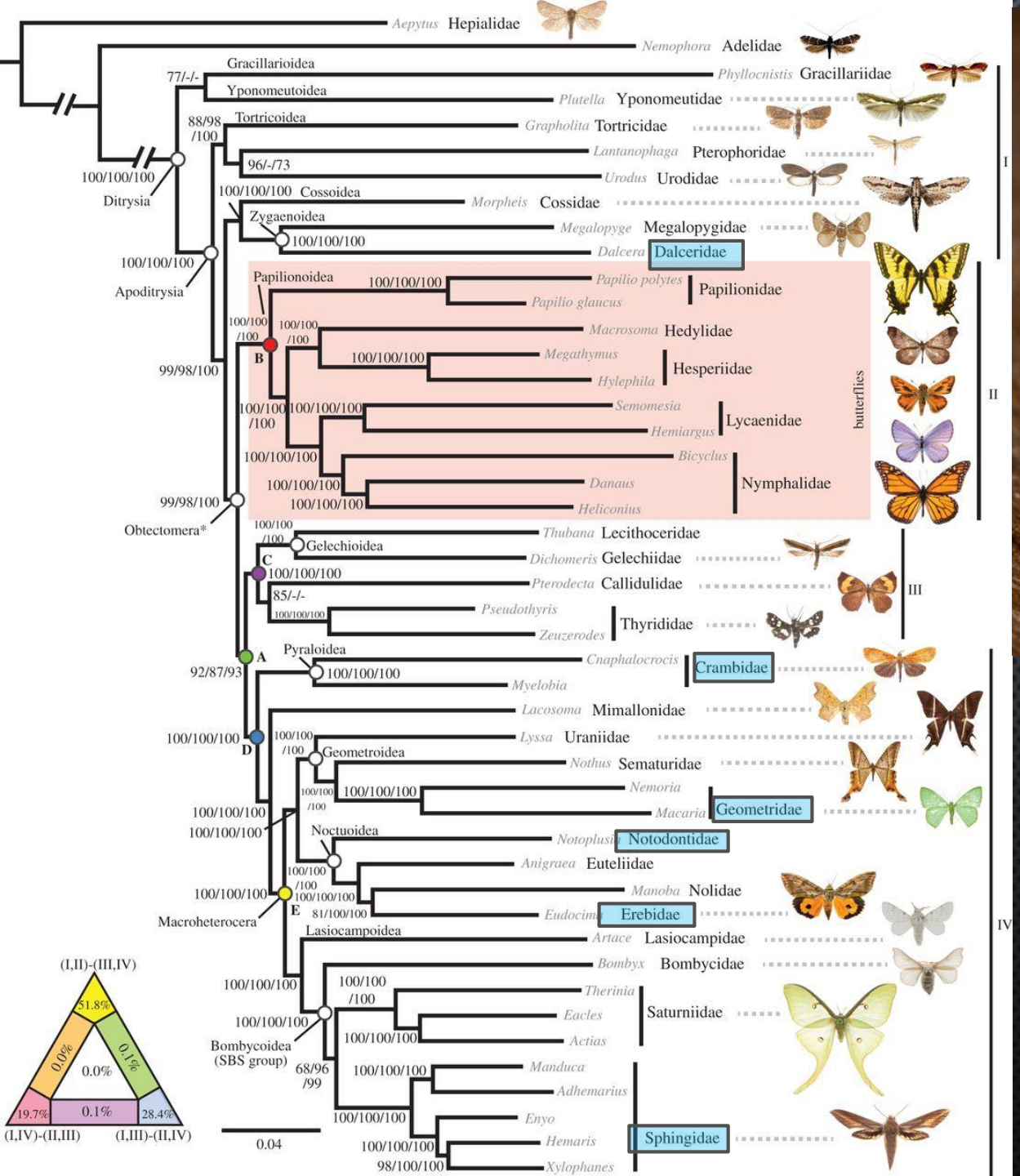
Aepytus Hepialidae
Nemophora Adelidae
Gracillarioidea
77/-/-
Phyllocnistis Gracillariidae
Yponomeutoidea
Plutella Yponomeutidae
88/98
/100
Tortricoidea
Grapholita Tortricidae
Lantanophaga Pterophoridae
96/-/73
Urodus Urodidae
100/100/100
Ditrysia
100/100/100 Cossoidea
Morpheis Cossidae
Zygaenoidea
Megalopyge Megalopygidae
100/100/100
Dalcera Dalceridae
100/100/100
Apoditrysia
Papilionoidea
100/100/100
Papilio polytes
Papilio glaucus
Papilionidae
100/100
/100
B
Macrosoma Hedylidae
100/100
/100
Megathymus
Hylephila
Hesperiidae
99/98/100
100/100
/100
100/100/100
Semomesia
Hemiargus
Lycaenidae
butterflies
100/100/100
Bicyclus
100/100/100
Danaus
Heliconius
Nymphalidae
99/98/100
Obtectomera*
100/100
/100
Gelechioidea
Thubana Lecithoceridae
C
Dichomeris Gelechiidae
100/100/100
Pterodecta Callidulidae
85/-/-
100/100/100
Pseudothyris
Zeuzerodes
Thyrididae
A
Pyraloidea
92/87/93
Cnaphalocrocis Crambidae
100/100/100
Myelobia
Lacosoma Mimallonidae
100/100/100
D
100/100
/100
Lyssa Uraniidae
Geometroidea
Nothus Sematuridae
100/100
/100
100/100/100
Nemoria
Macaria Geometridae
100/100/100
100/100/100
Noctuoidea
Notoplusia Notodontidae
Anigraea Euteliidae
100/100
/100
100/100/100
100/100/100
Manoba Nolidae
E
81/100/100
Eudocima Erebidae
Macroheterocera
Lasiocampoidea
Artace Lasiocampidae
Bombyx Bombycidae
100/100/100
100/100
/100
Therinia
100/100/100
Eacles
Actias
Saturniidae
Bombycoidea
(SBS group)
68/96
/99
100/100/100
Manduca
Adhemarius
100/100/100
Enyo
100/100/100
Hemaris
Sphingidae
98/100/100
Xylophanes
0.04
I
II
III
IV
(I,II)-(III,IV)
51.8%
0.0%
0.1%
0.0%
19.7%
0.1%
28.4%
(I,IV)-(II,III)
(I,III)-(II,IV)

Acknowledgments

The Kawahara Lab

Jesse Breinholt
Geena Hill
Nicholas Homziak
Lary Reeves

https://www.floridamuseum.ufl.edu/mcguire/kawahara/

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David Blackburn
Andrei Sourakov

The Barber Lab

Brian Leavell
Krystie Miner

UF Nanoscale Research Facility

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Edward Stanley

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