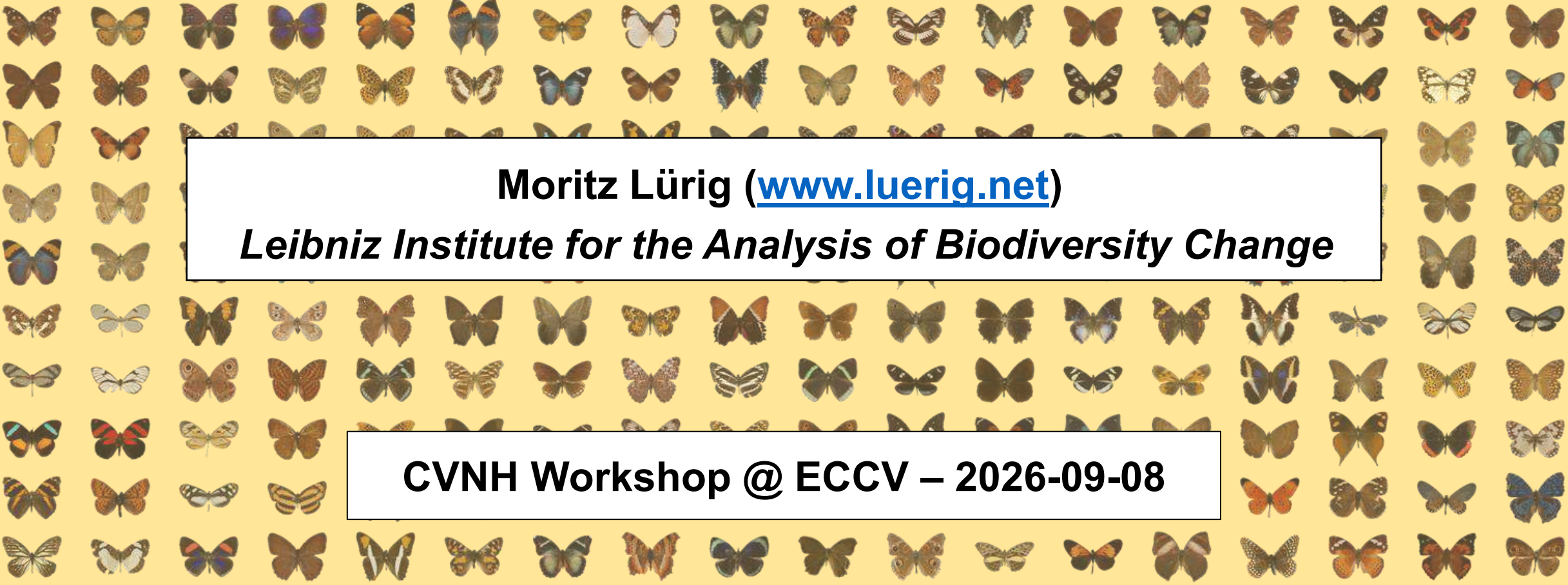




Navigating the complexity of butterfly wing patterns using computer vision



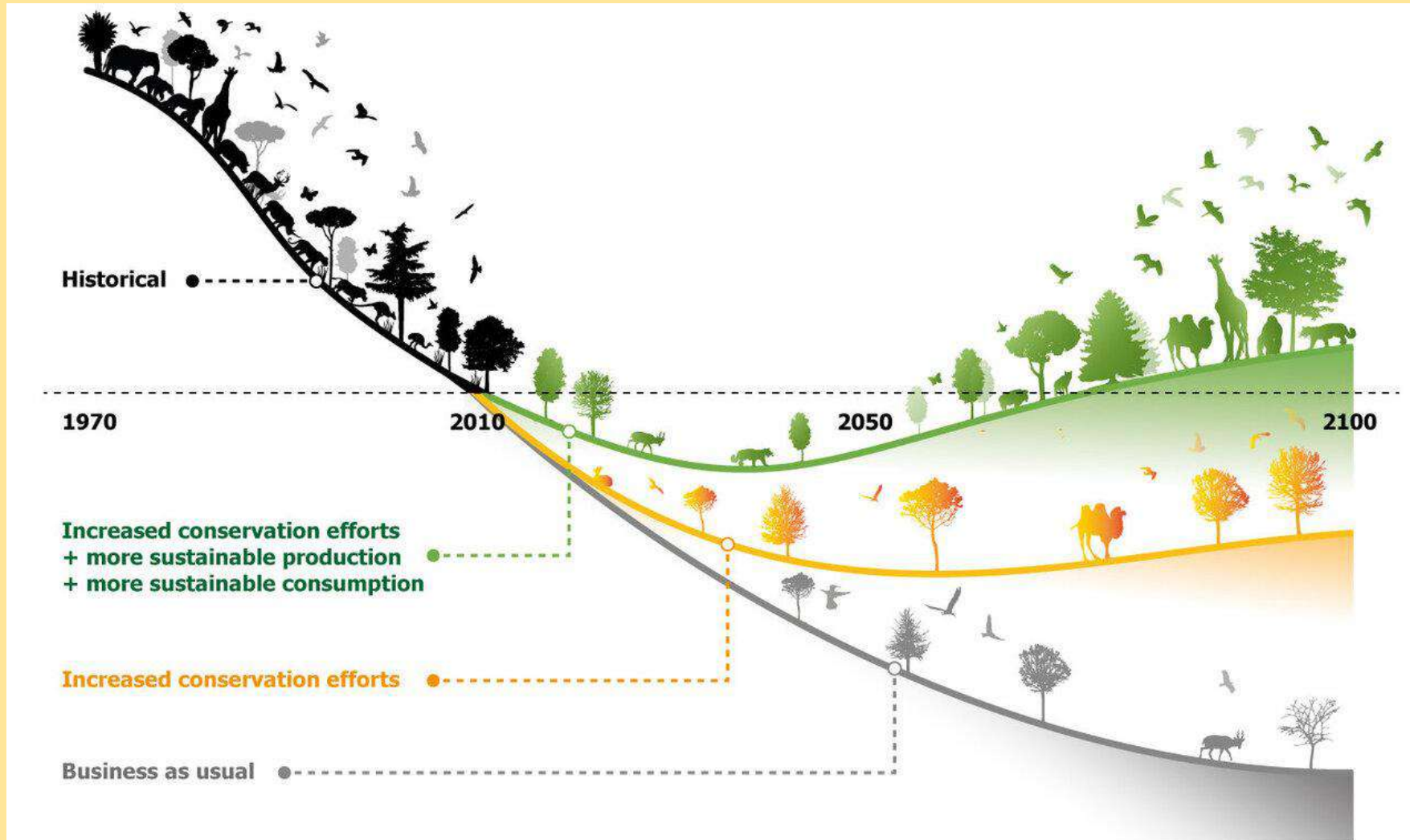
Moritz Lürig (www.luerig.net)

Leibniz Institute for the Analysis of Biodiversity Change

CVNH Workshop @ ECCV – 2026-09-08

Biodiversity matters

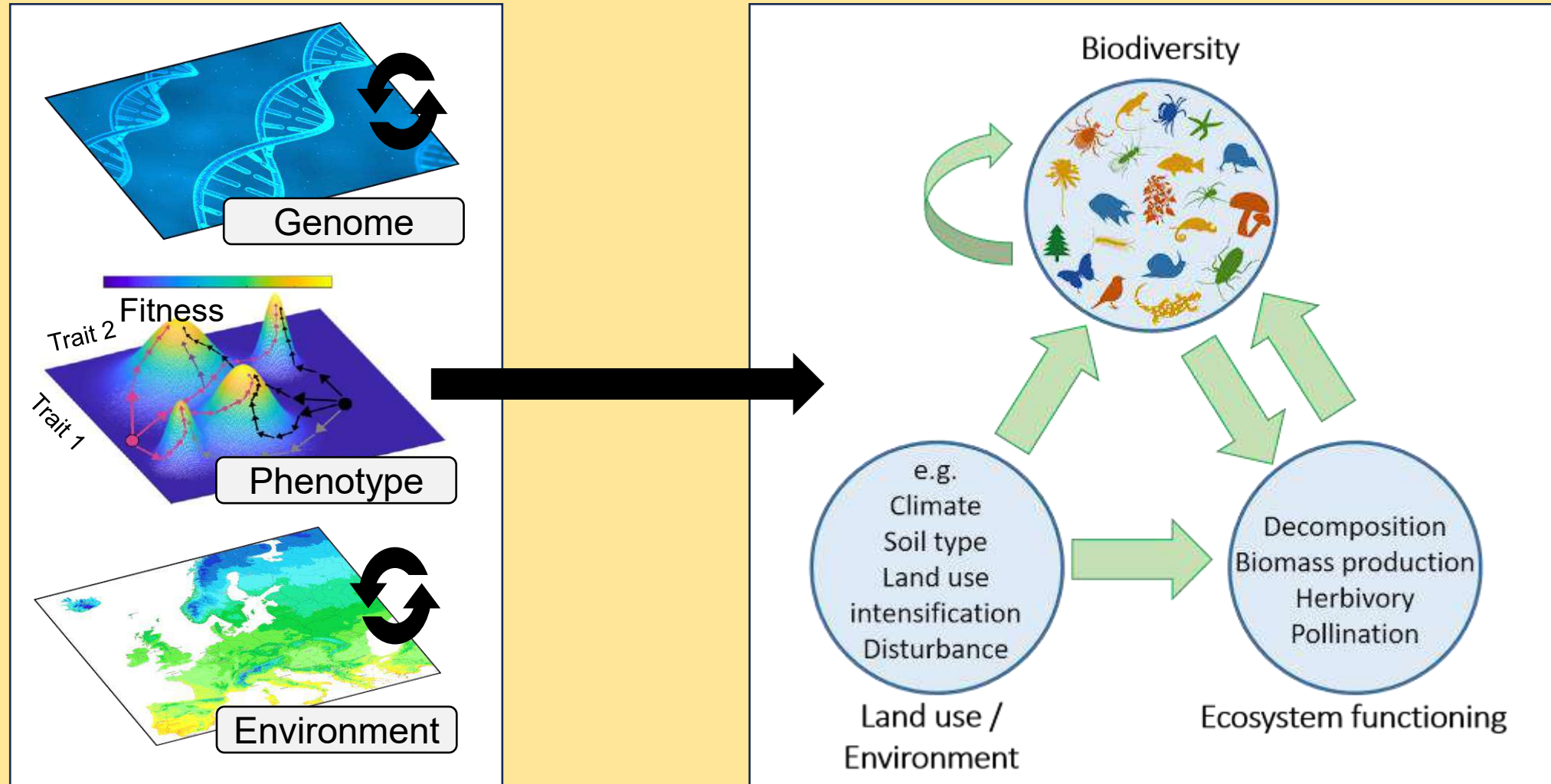
We are losing biodiversity at alarming rates



This artwork illustrates the main findings of the article, but does not intend to accurately represent its results (<https://doi.org/10.1038/s41586-020-2705-y>)

Phenotypes matter

Our understanding of biodiversity and its loss is incomplete without phenotypes



Museums matter

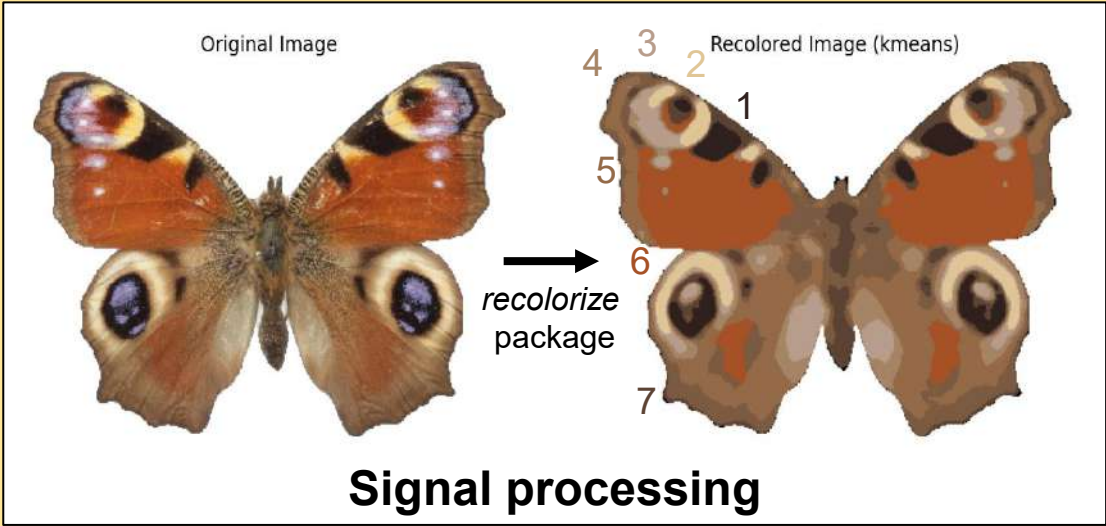
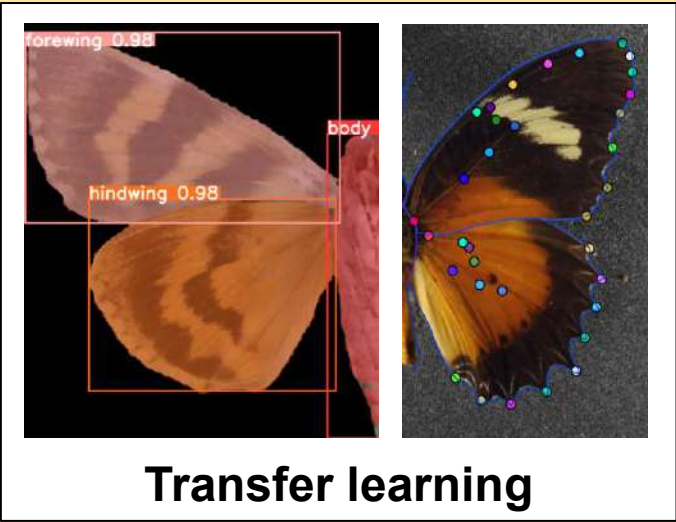
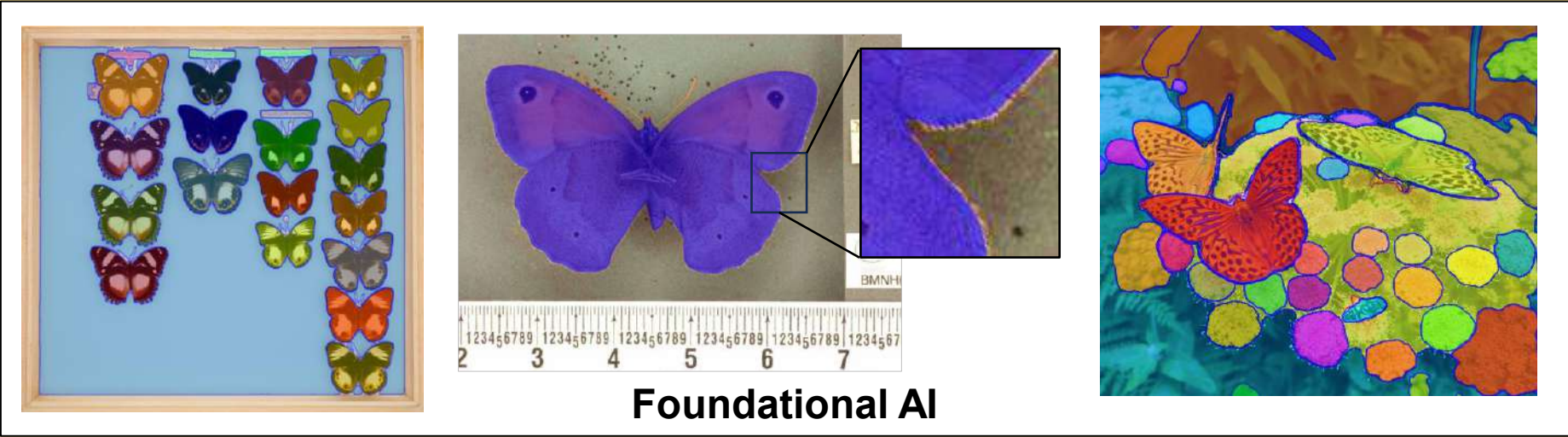
NHMs are treasure troves full of phenotypes (estimated 2-3 billion [Ariño 2010])



<https://gigamacro.com>

Computer vision

CV is a key method to collect phenotypic information from NHM collections



Aposematic coloration in butterflies

Aposematic color patterns are thought to be a major driver of diversification in butterflies and moths.



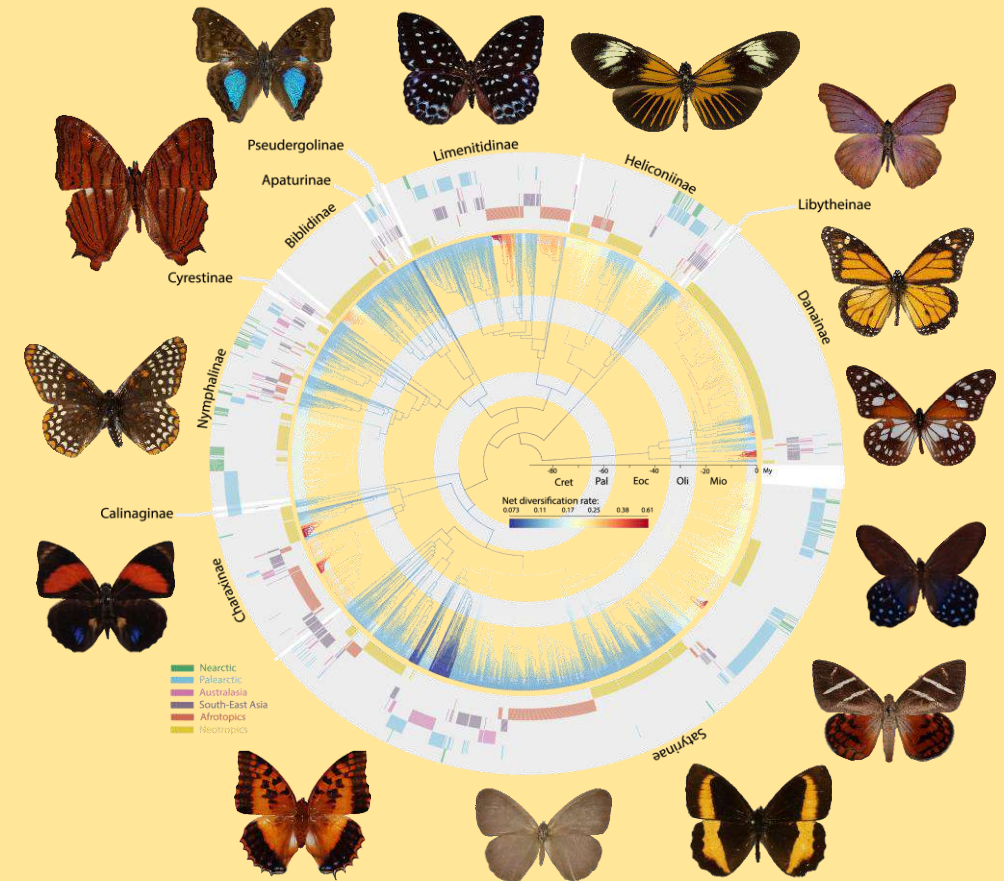
VS



Main question

How common is
aposematic coloration
among chemically
defended species?

Nymphalidae (~7000 species)



Chazot et al., 2021

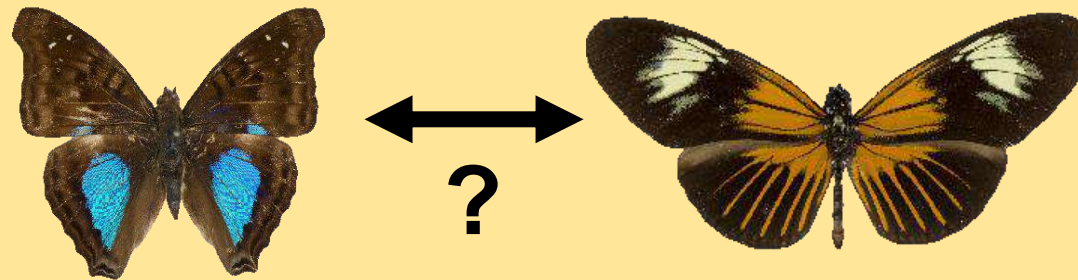
Major challenges

C1: Acquisition of a taxonomically broad dataset

C2: Extraction of phenotypic information from images

C3: Definition of aposematic color patterns

C4: Comparison of aposematic intensity among species



Step 1: Image download

- 250000 images in open online repositories



- 16700 specimens with both dorsal and ventral perspective (33400 images, 2500 species)
- Literature survey to assign three levels of chemical defense to 350 species (low, medium, high probability)

Step 2: Phenotype extraction

- High-throughput segmentation of images (*Grounded SAM*)



Step 2: Phenotype extraction

- High-throughput segmentation of images (*Grounded SAM*)



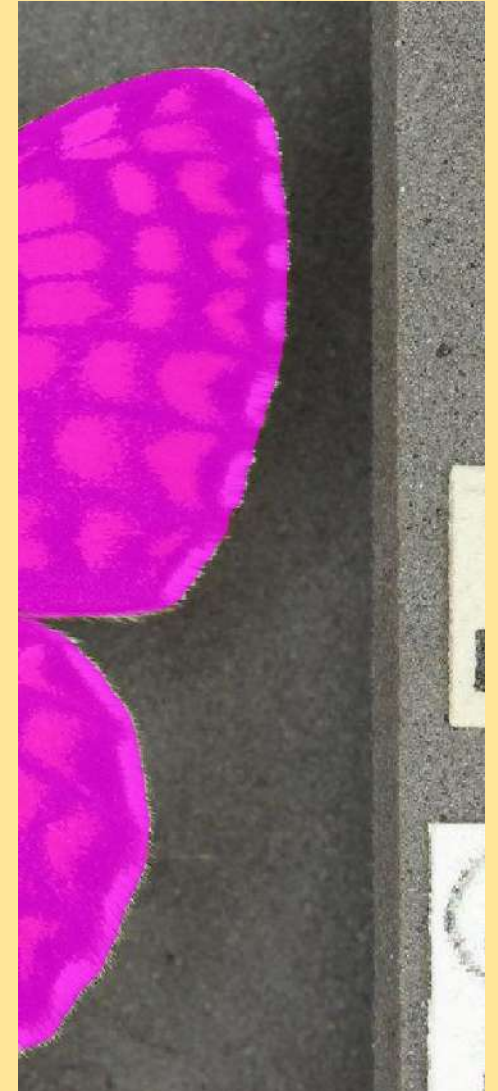
Step 2: Phenotype extraction

- High-throughput segmentation of images (*Grounded SAM*)



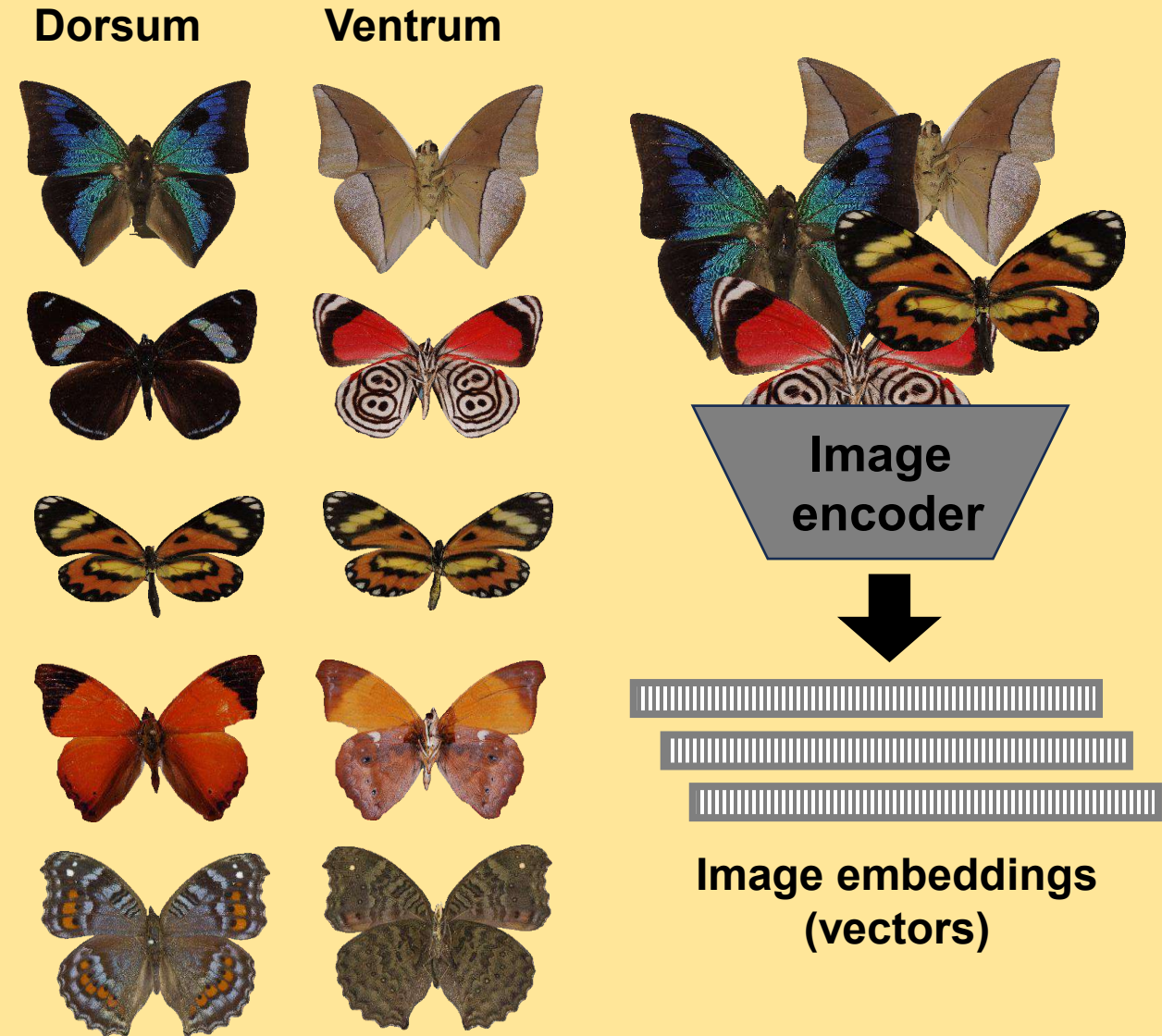
Step 2: Phenotype extraction

- High-throughput segmentation of images (*Grounded SAM*)

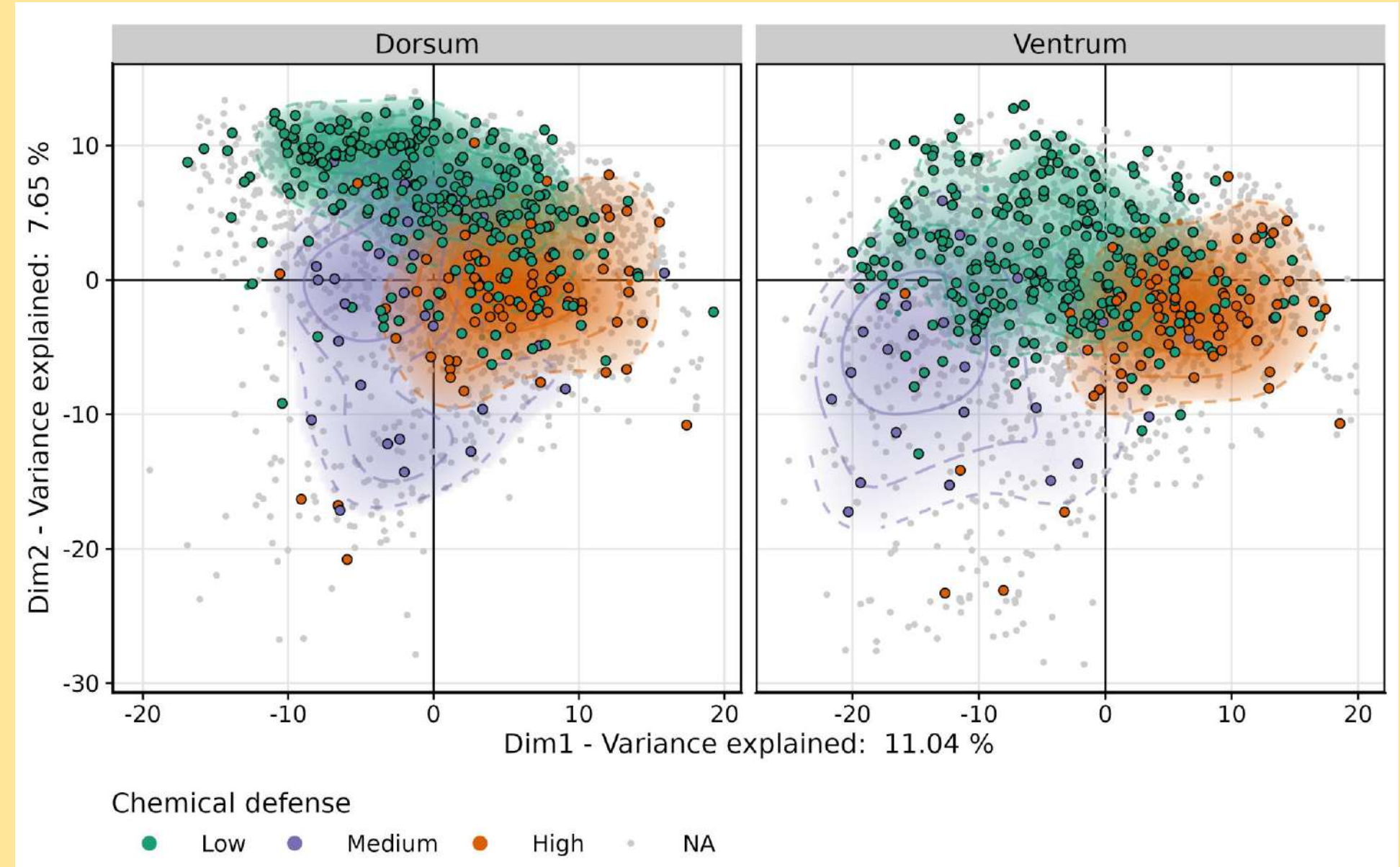


Step 3: Definition of aposematism

- Encoding of information using a pretrained Vision Transformer (*UNICOM*)
- The *UNICOM* model was trained with a metric loss function, so distances in feature-space can be interpreted.
- Condenses 2D visual information to 1D vectors - crucial for analyses

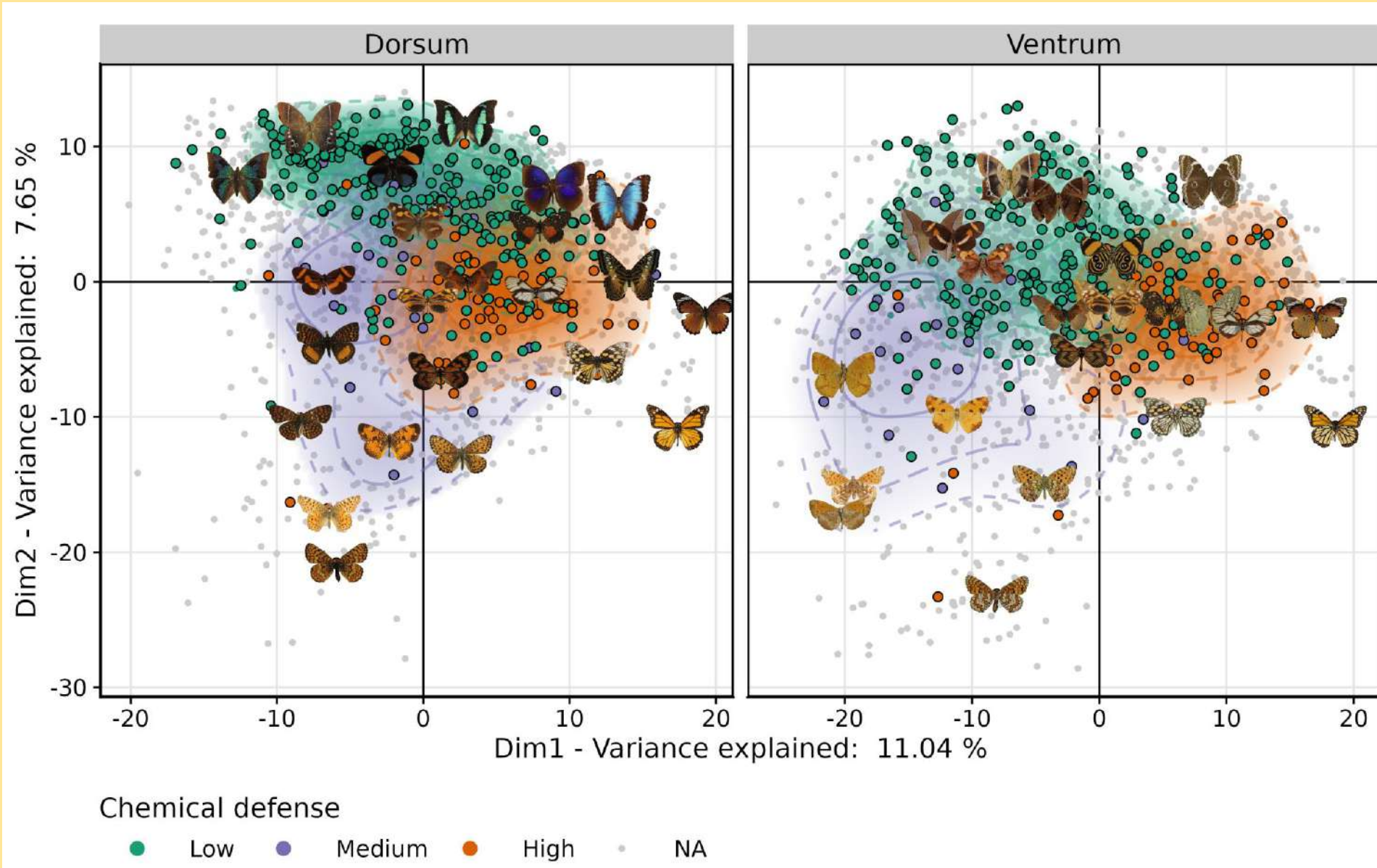


Step 3: Definition of aposematism



Principal component analysis of 768 dim. embedding vectors

Step 3: Definition of aposematism



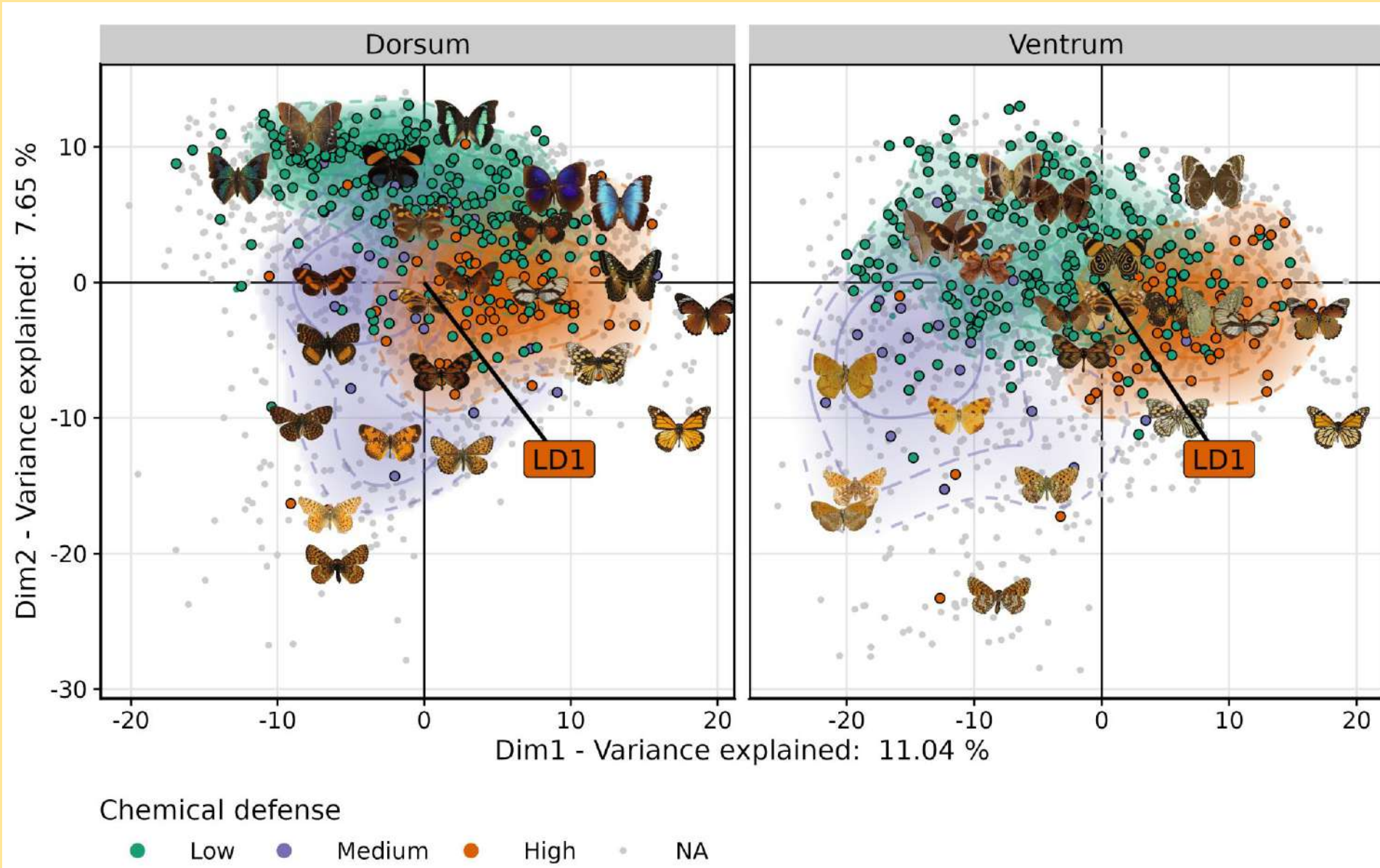
Principal component analysis of 768 dim. embedding vectors

mvMORPH
manova.gls

Phylogenetically informed multivariate test for differences between chemically defended species

Dorsum $P < 0.001$
Ventrums $P < 0.001$

Step 3: Definition of aposematism



Principal component analysis of 768 dim. embedding vectors

mvMORPH
manova.gls

Phylogenetically informed multivariate test for differences between chemically defended species

Dorsum $P < 0.001$
Ventrum $P < 0.001$

Linear discriminant analysis using 7 PCs

Results

nature communications



Article

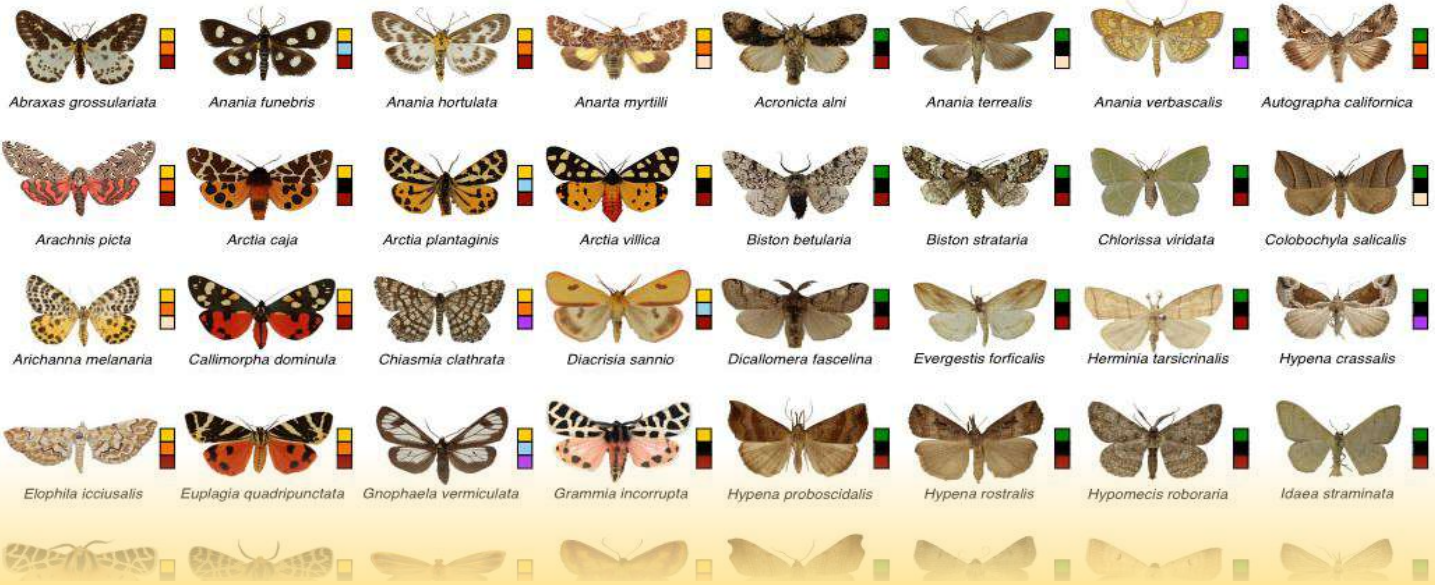
<https://doi.org/10.1038/s41467-024-45329-5>

Predator selection on phenotypic variability of cryptic and aposematic moths

Received: 13 April 2023

Ossi Nokelainen^{1,2,3}, Sanni A. Silvasti^{2,4}, Sharon Y. Strauss^{5,6},
Niklas Wahlberg⁷ & Johanna Mappes^{1,6}

Accepted: 17 January 2024



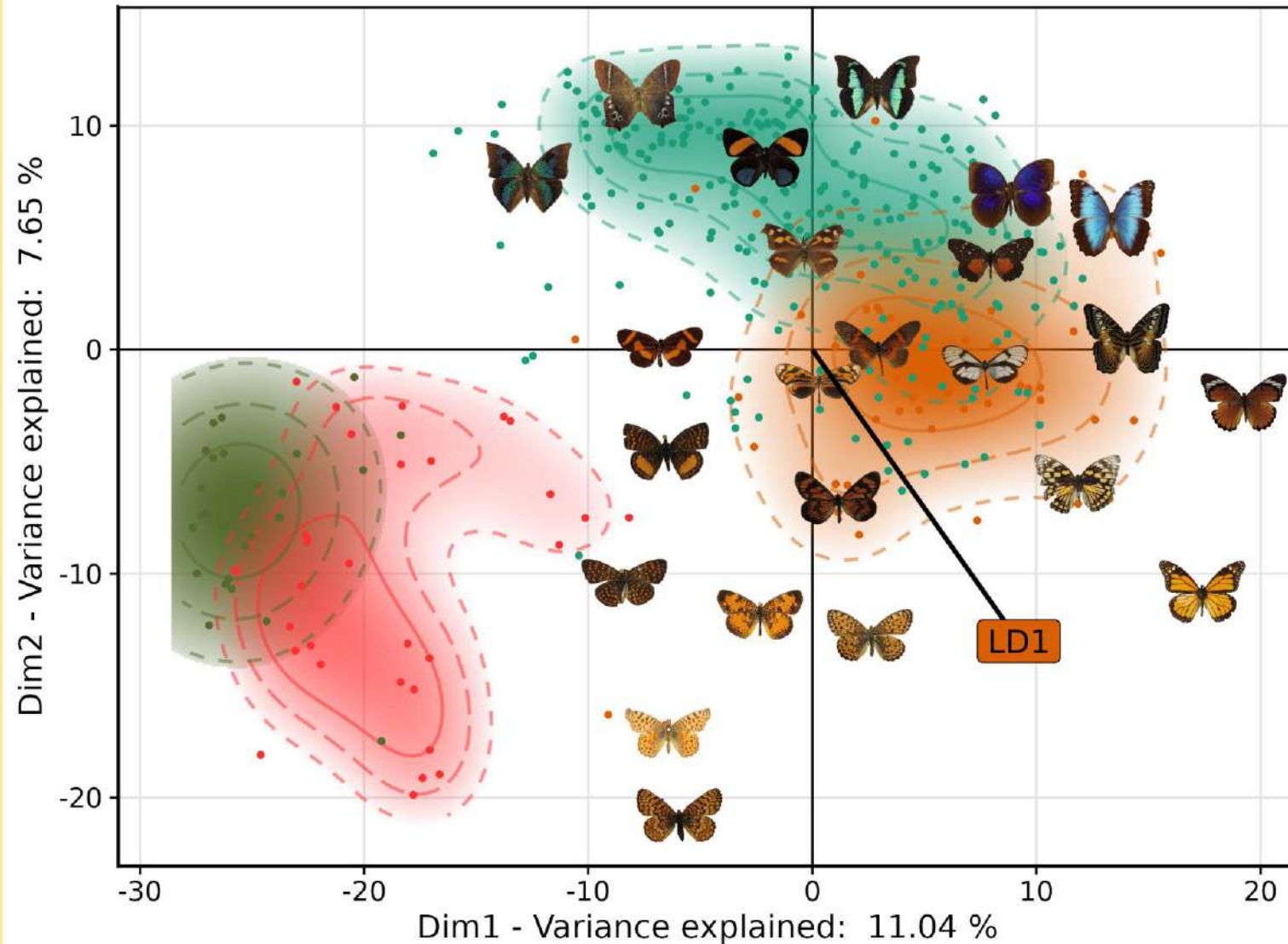
Aposematism



Camouflage



Step 3: Definition of aposematism

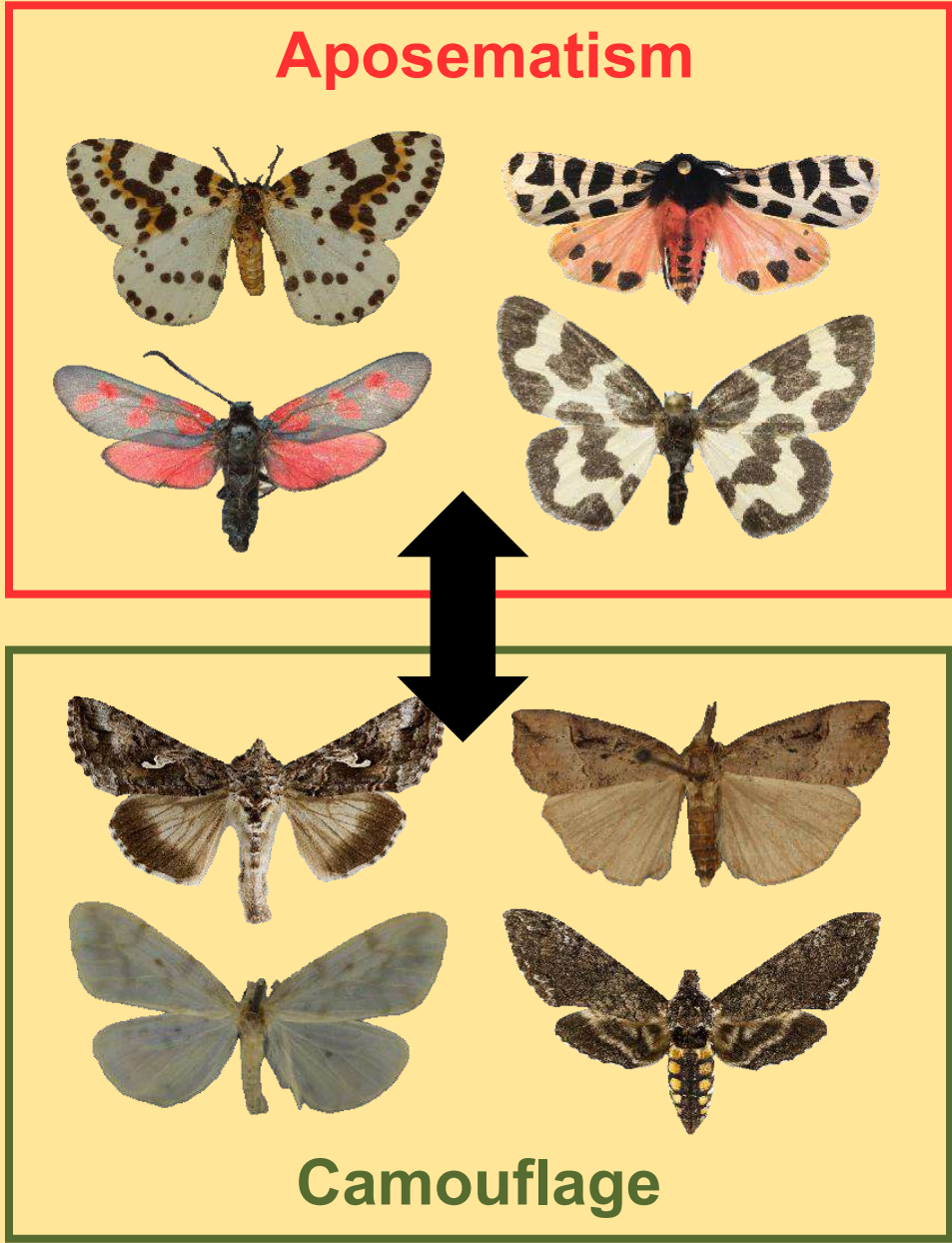
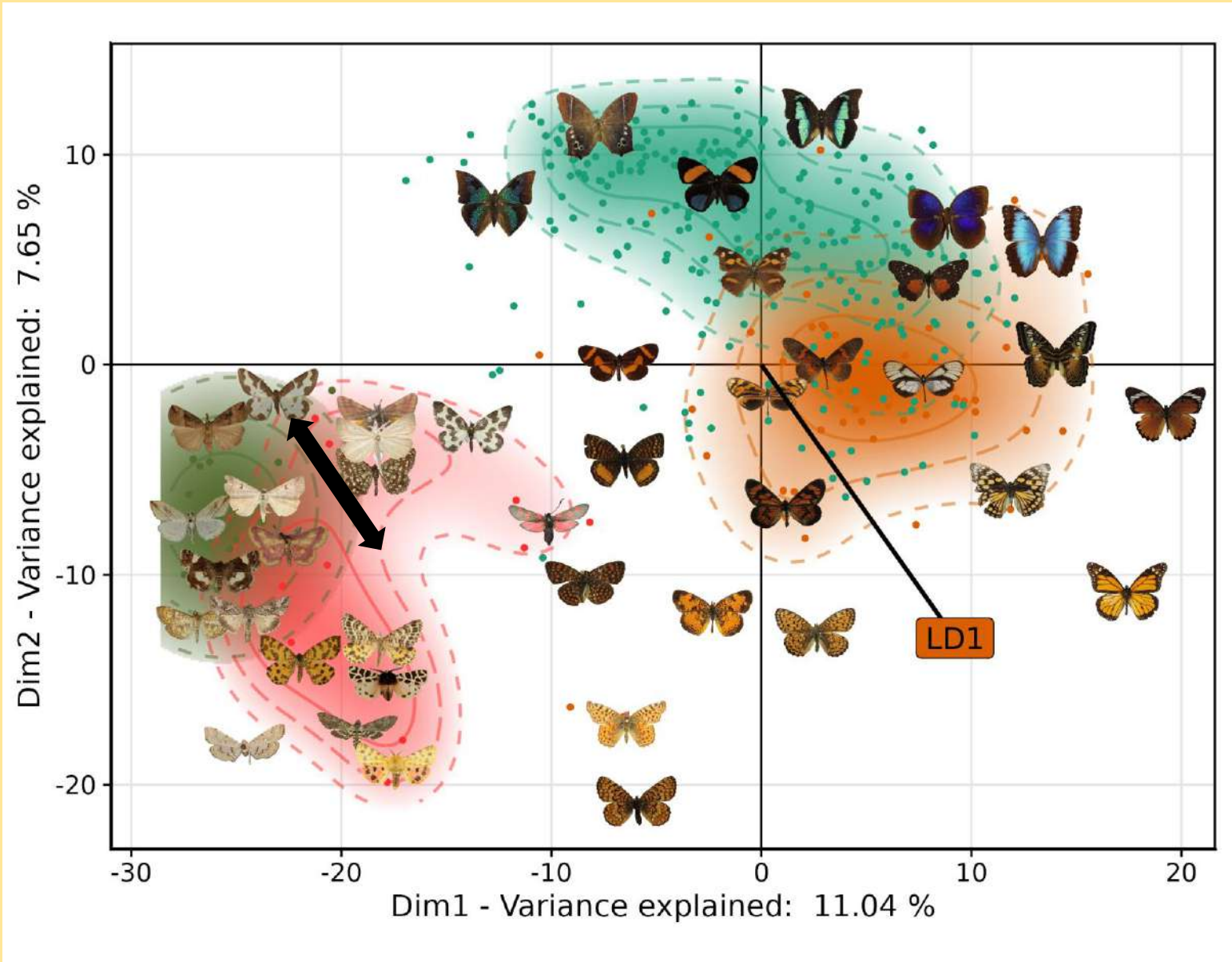


Aposematism

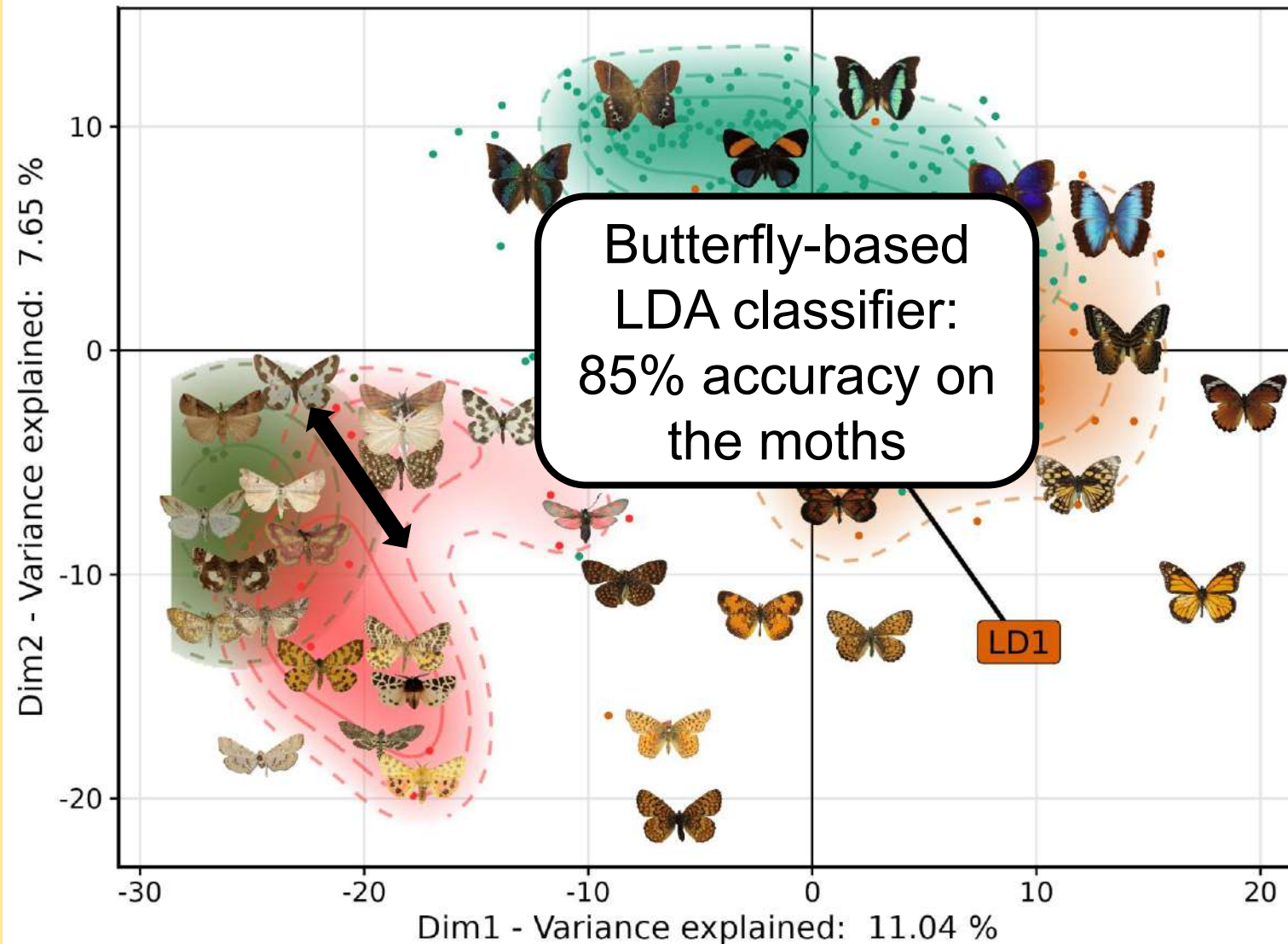


Camouflage

Step 3: Definition of aposematism



Step 3: Definition of aposematism



Aposematism

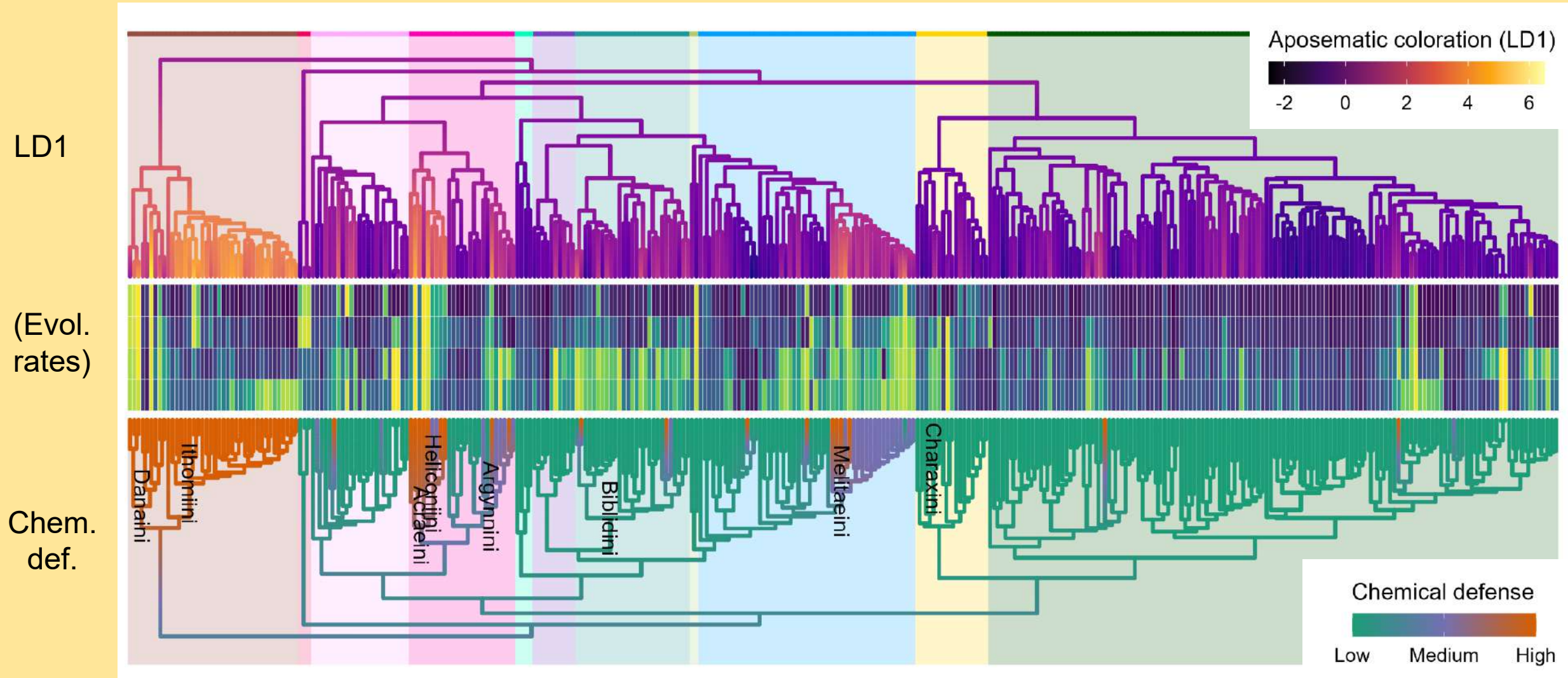


Camouflage



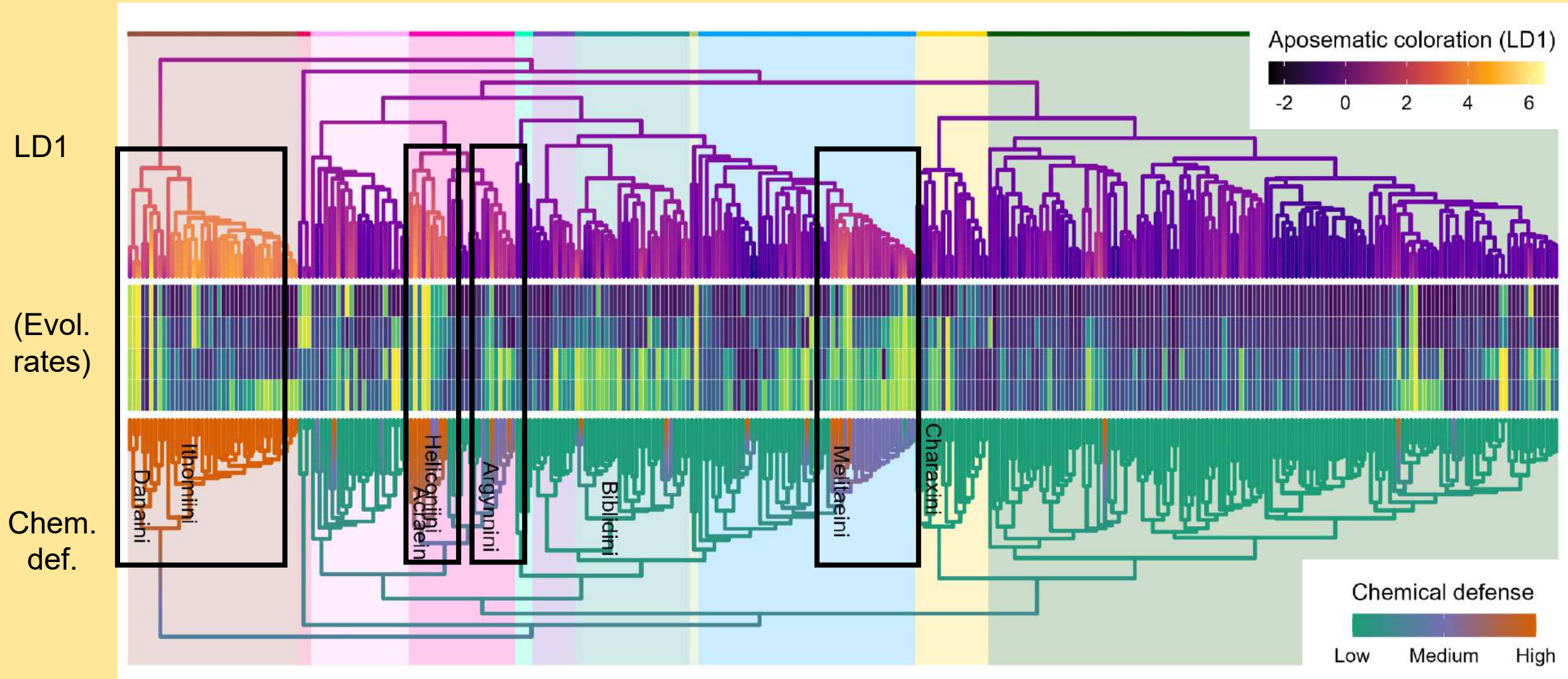
Step 4: Phylogenetic comparison

- Aposematic color patterns evolved repeatedly



Step 4: Phylogenetic comparison

- Aposematic color patterns evolved repeatedly

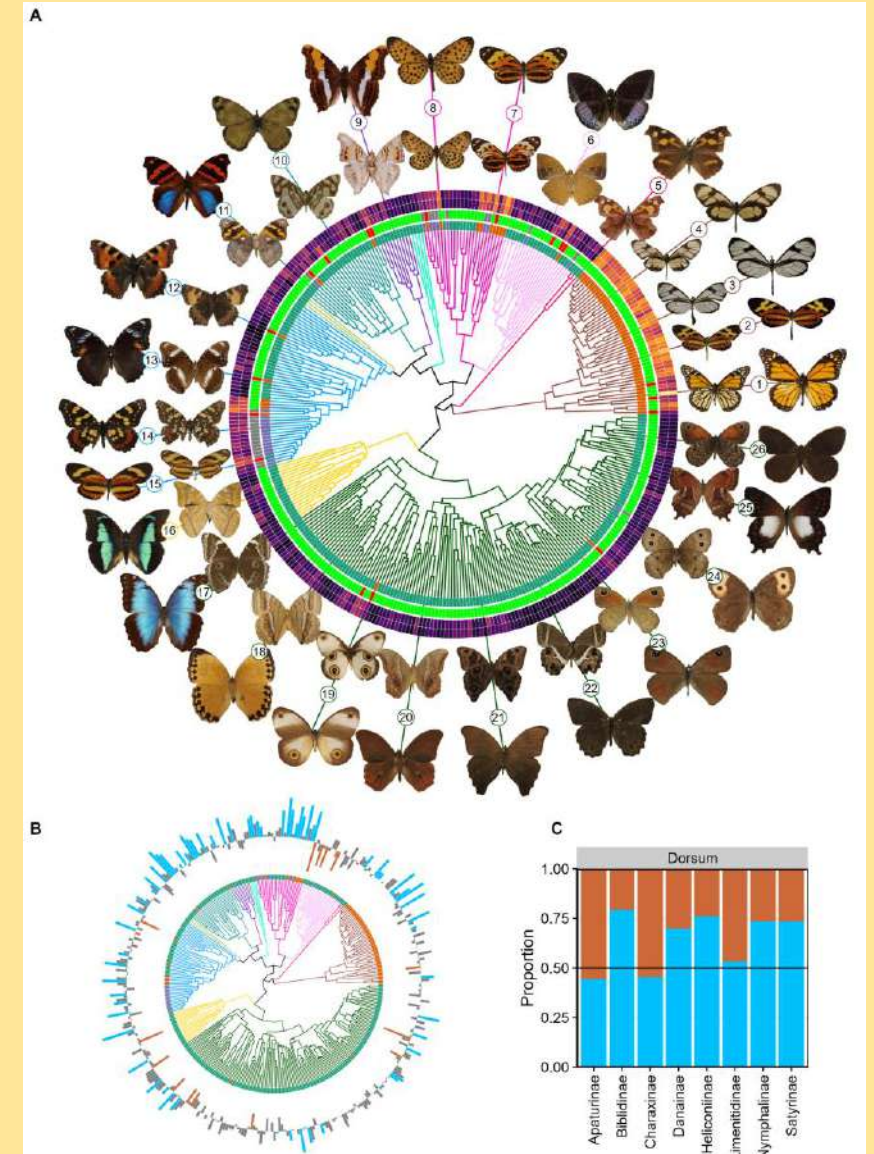


Aposematic color patterns are the dominant axis of phenotypic diversification in Nymphalid butterflies

 Moritz D. Lürig, Leila T. Shirai, Luísa L. Mota, Keith Willmott, André V. L. Freitas, Arthur Porto

doi: <https://doi.org/10.1101/2025.09.30.678834>

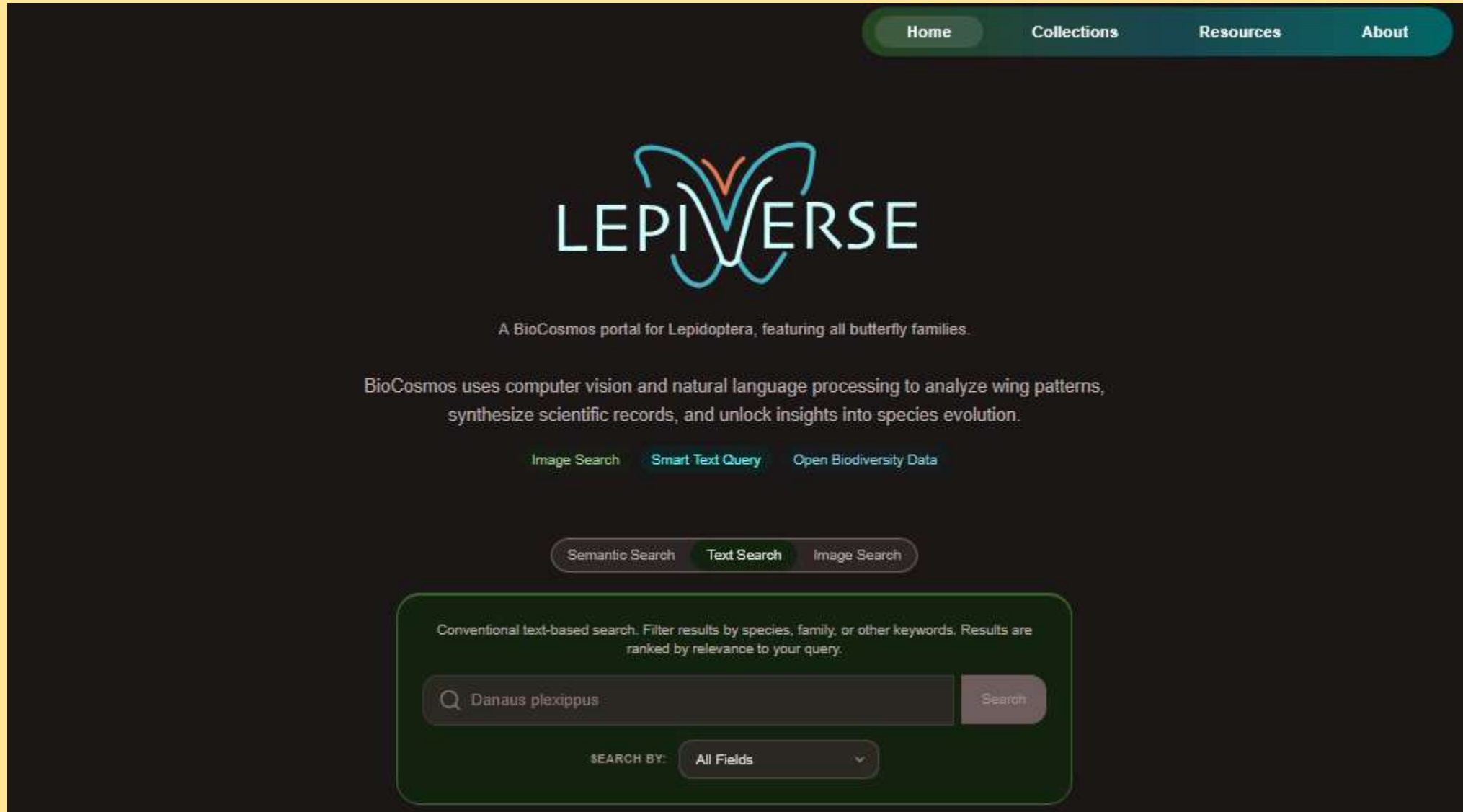
This article is a preprint and has not been certified by peer review [what does this mean?].



Summary

- Aposematism is a major axis of phenotypic diversification in nymphalid butterflies (and moths!)
- Segmentation models allow for rapid extraction of phenotypes from standardized images of museum specimens
- Vision models can encode high-dimensional traits and allow for comparison of complex phenotypes
- The analysis of museum collections with CV provides ample opportunity for data-driven biodiversity research!

Outlook



<https://lepiverse.com/>

Acknowledgements



Arthur Porto



Leila Shirai



Luísa Mota



Heru Handika



André Victor
Lucci Freitas

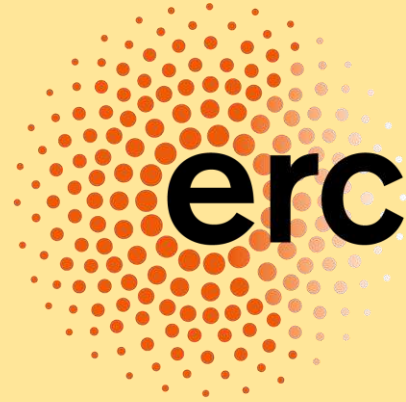


Keith Willmott





Funded by
the European Union



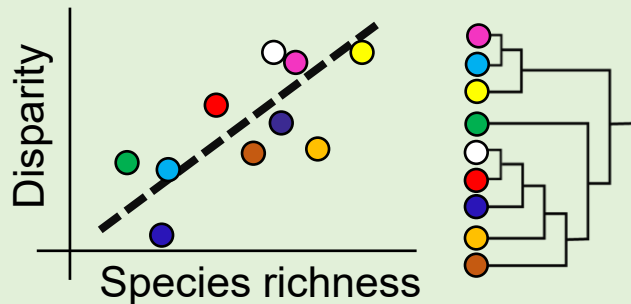
European Research Council
Established by the European Commission

ERC Starting Grant

***“The Evolution of
wing coloration in
Lepidoptera”***

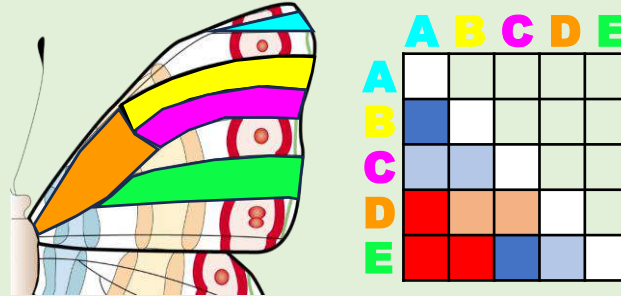
Context 1

Phylogeny and
macroevolution



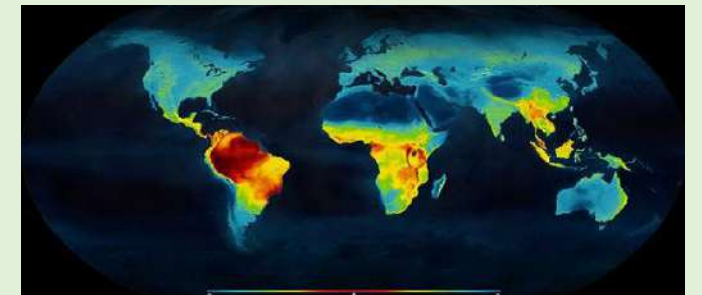
Context 2

Modularity and
integration

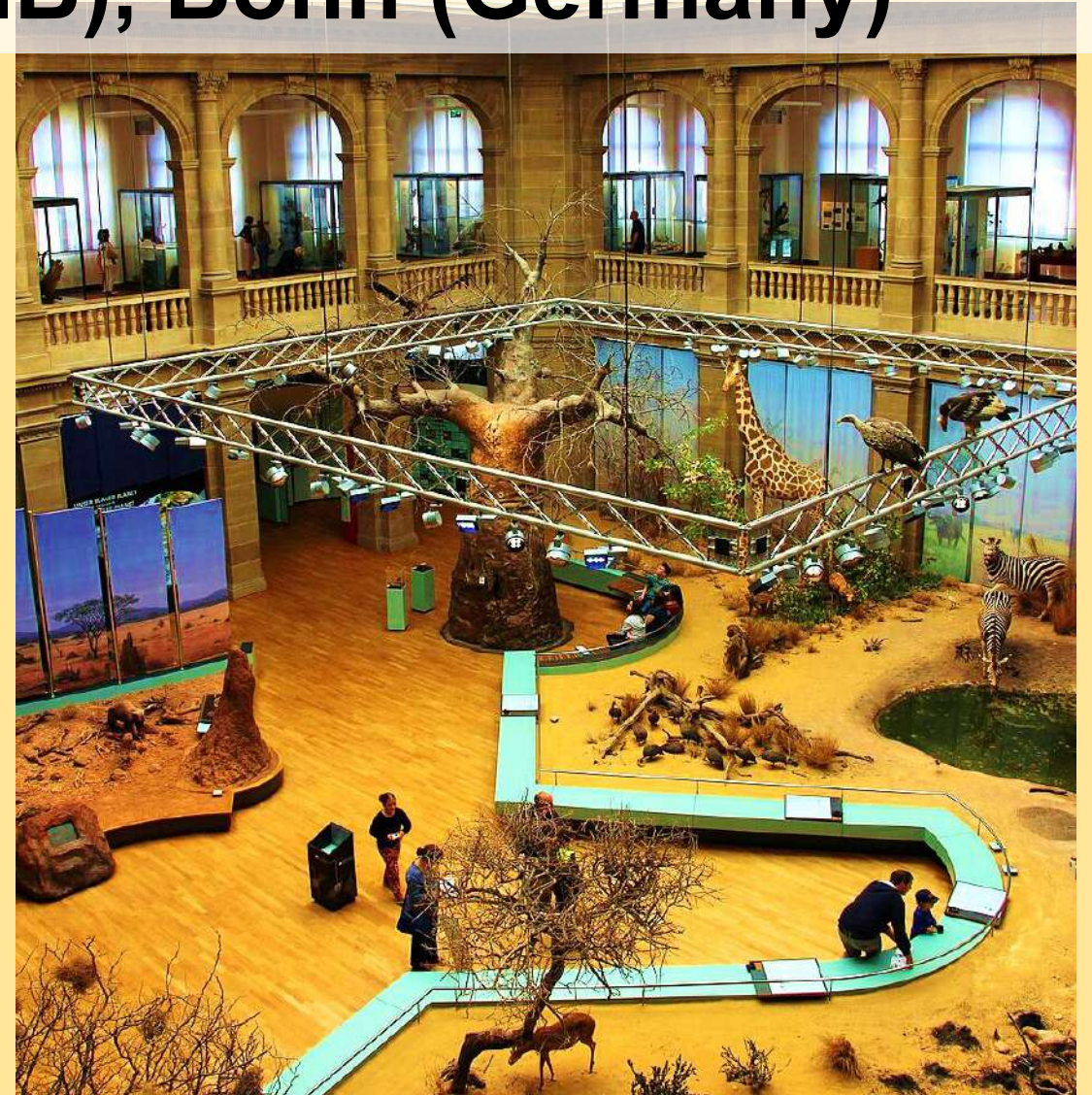
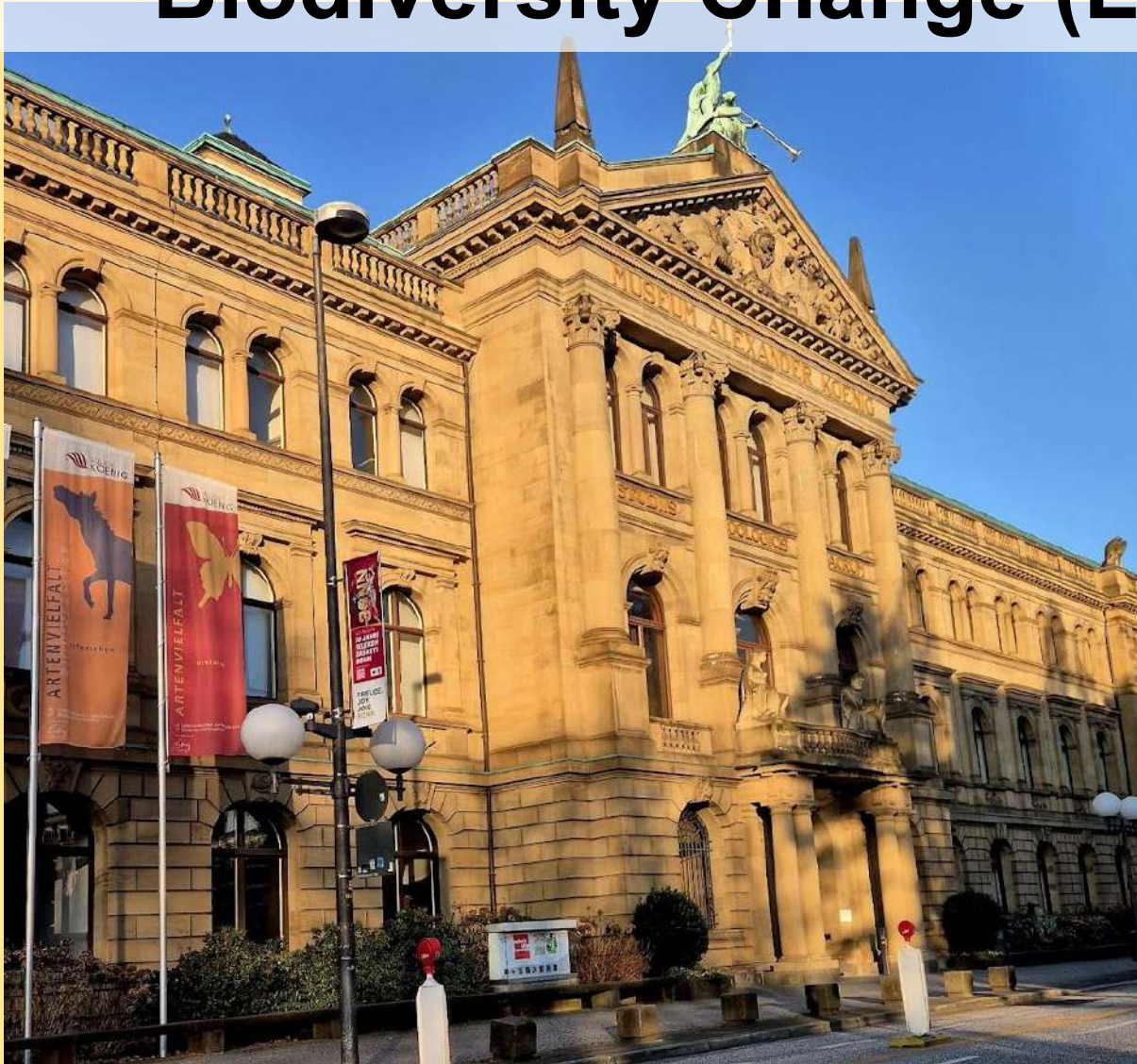


Context 3

Ecology and
biogeography



Museum Koenig / Leibniz Institute for the Analysis of Biodiversity Change (LIB), Bonn (Germany)





Thank you!
Questions?