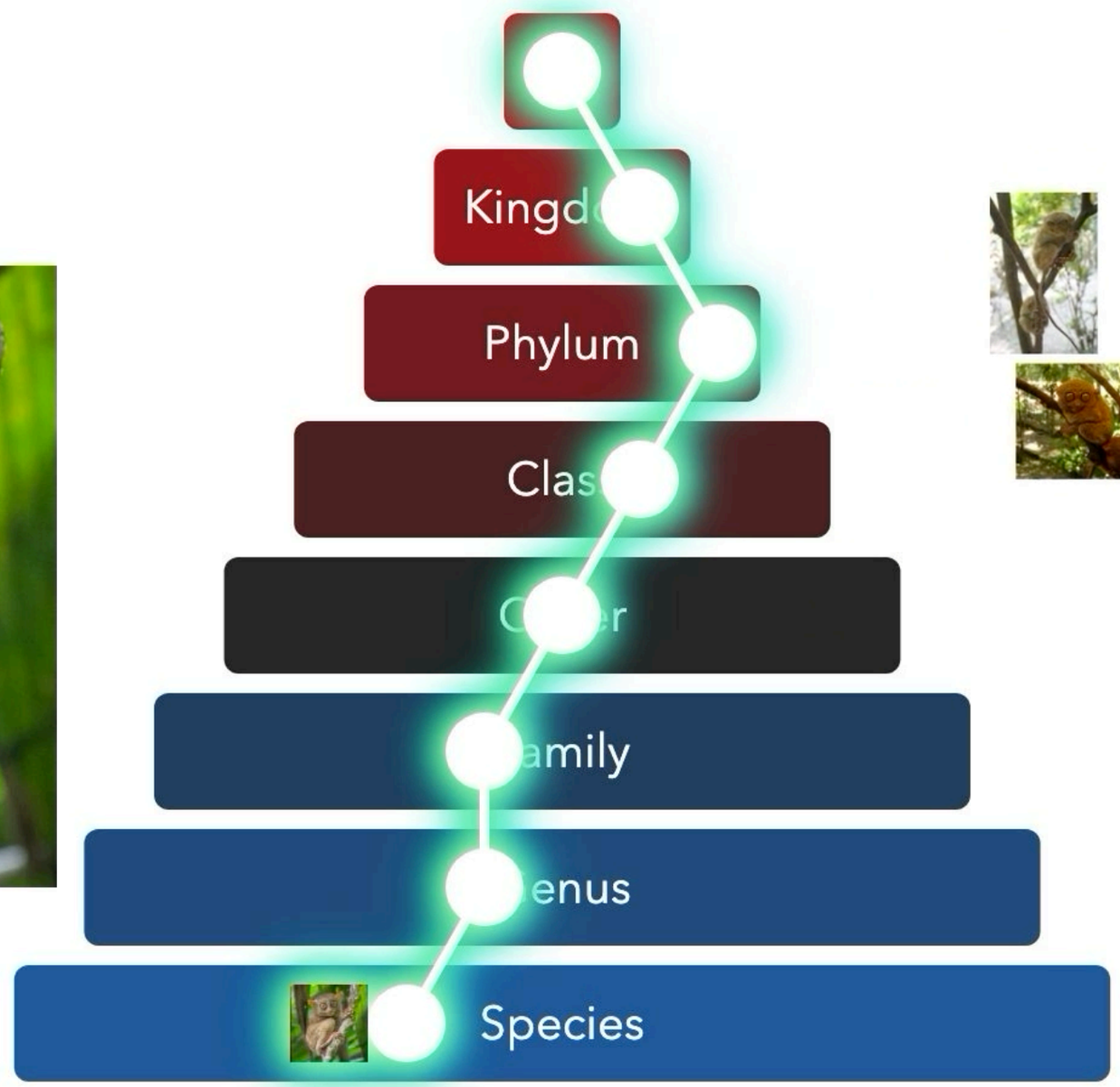
BioCLIP: A Vision Foundation Model for the Tree of Life

Sam Stevens*†, Jiaman Wu*, Matthew J Thompson, Elizabeth G Campolongo, Chan Hee Song, David Edward Carlyn, Li Dong, Wasila M Dahdul, Charles Stewart, Tanya Berger-Wolf, Wei-Lun Chao, Yu Su†

*Co-first authors, †Corresponding authors

Best Student Paper 🏆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C. syrichta

Tuia et al., *Nature* 2024

We need a foundation model for biology.

Tuia et al., *Nature* 2024

1. Biology is a fascinating computer vision problem.

2. Data is everything.

3. How does BioCLIP learn?

1. **Biology is a fascinating computer vision problem.**

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Hippodamia apicalis

Hippodamia tredecimpunctata

Onoclea sensibilis

Onoclea hintonii

Extremely fine-grained classes

Hippodamia apicalis

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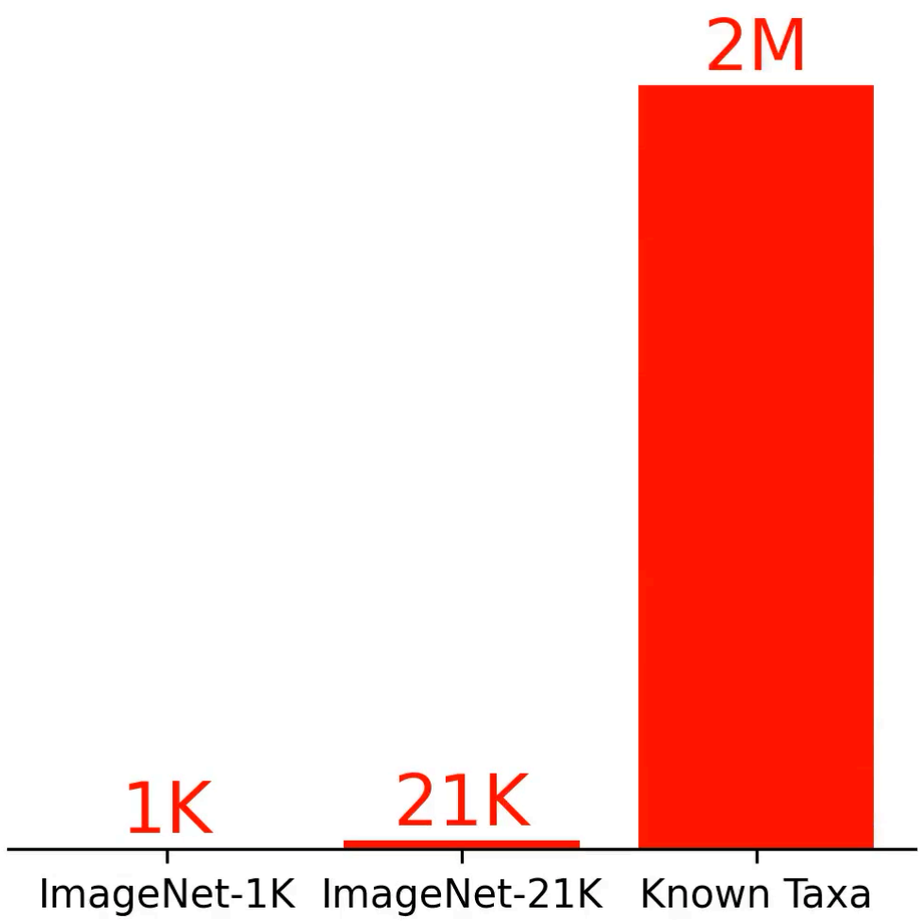
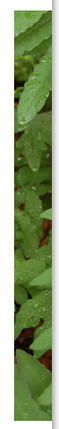
Extremely fine-grained classes



Many different classes

Hippodamia apicalis

Hippodamia tredecimpunctata



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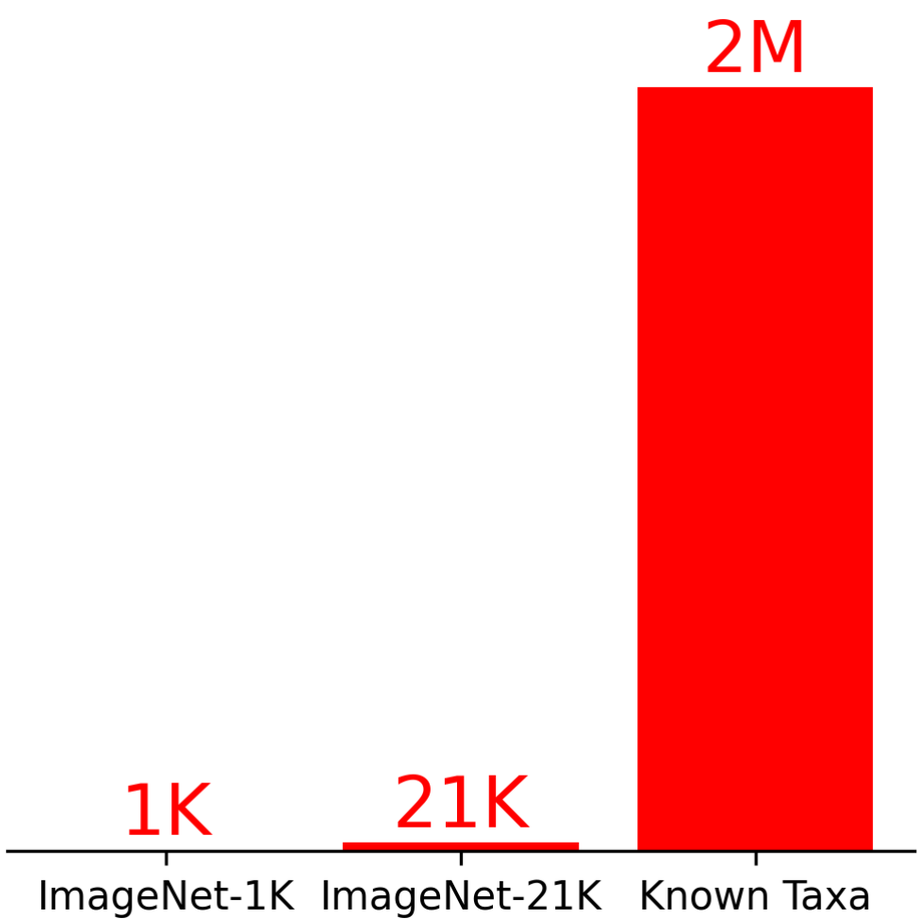

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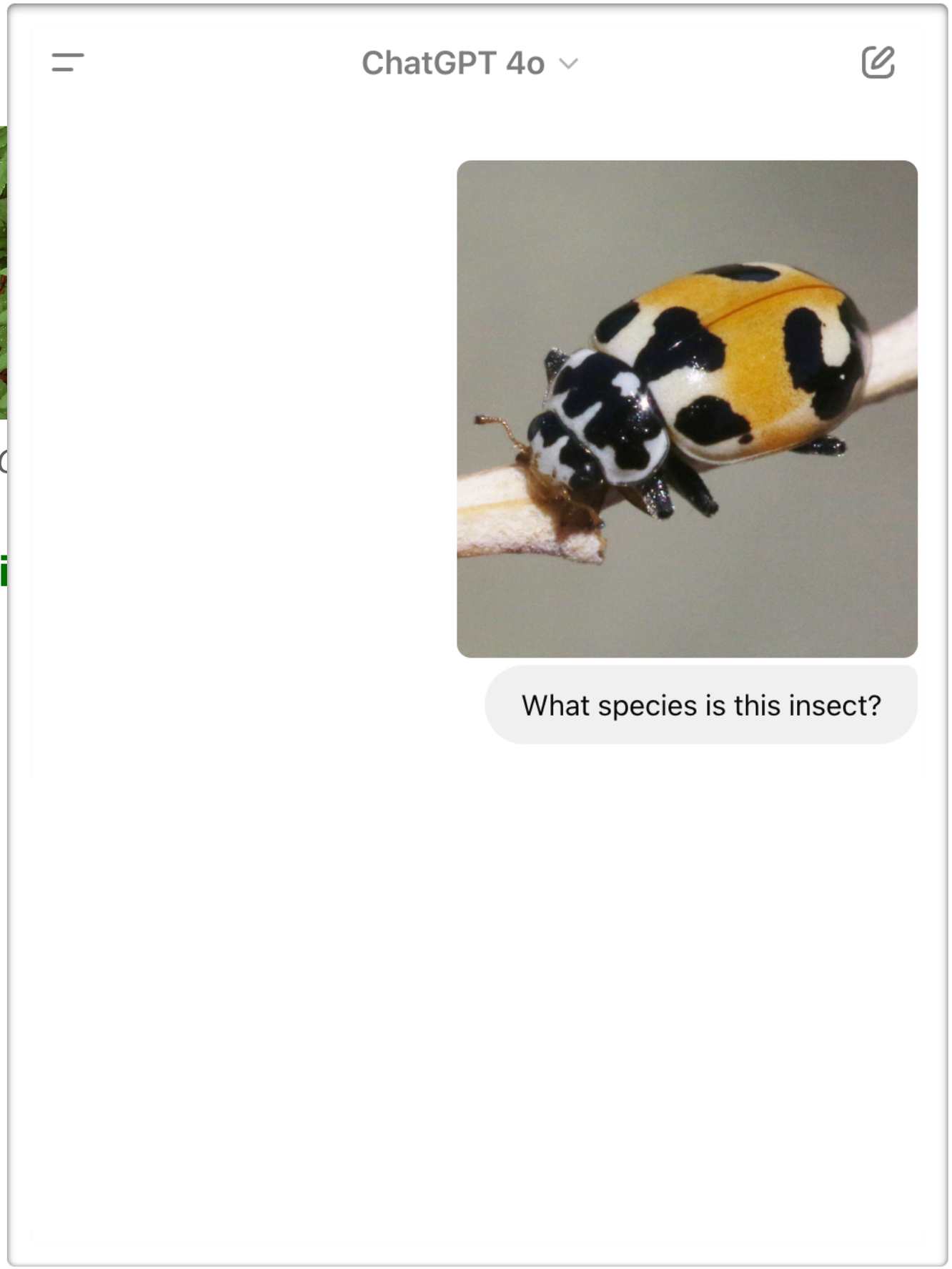

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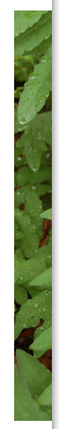

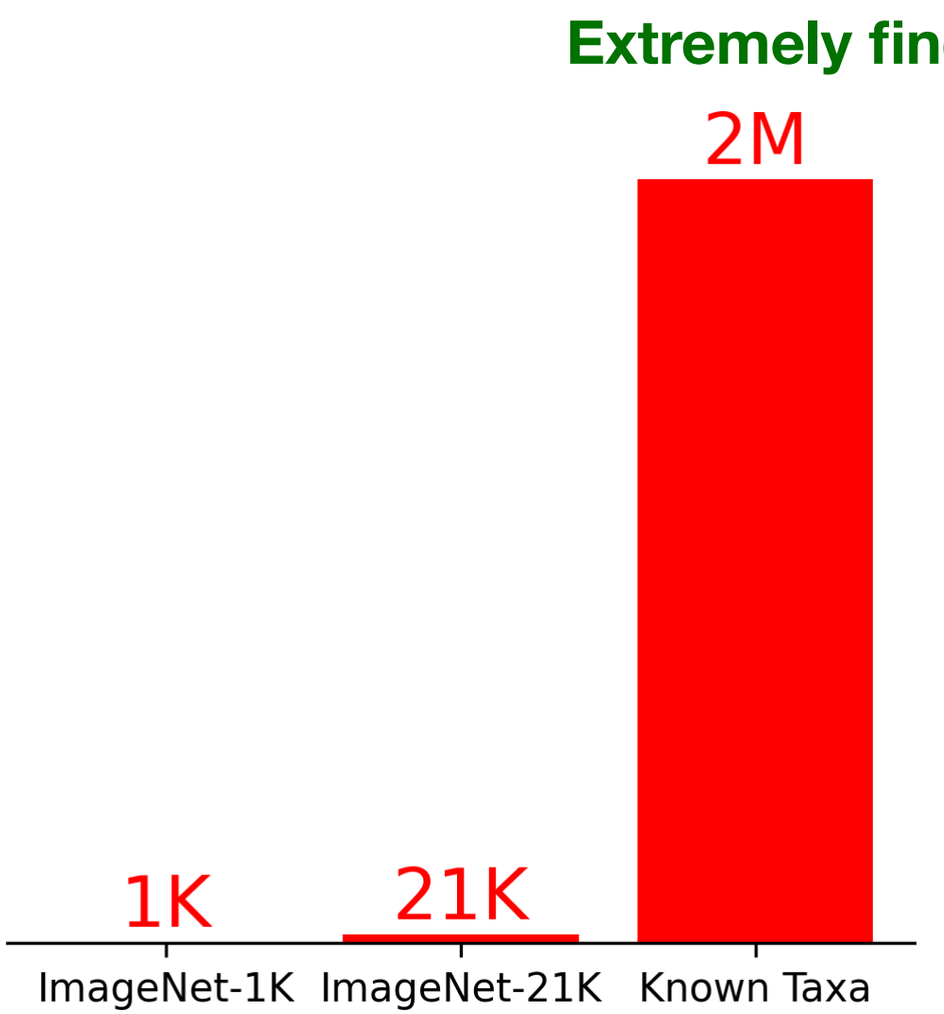

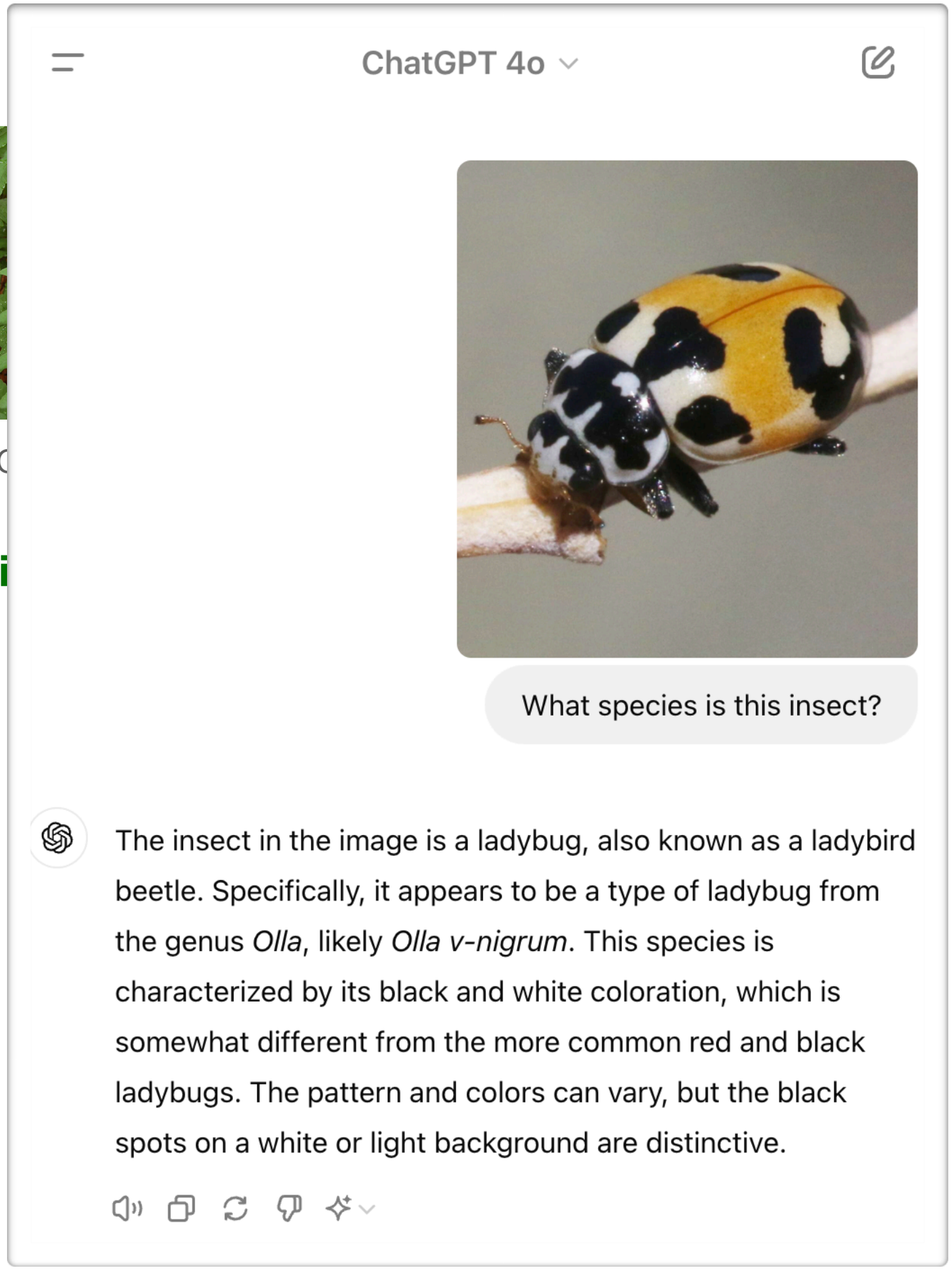

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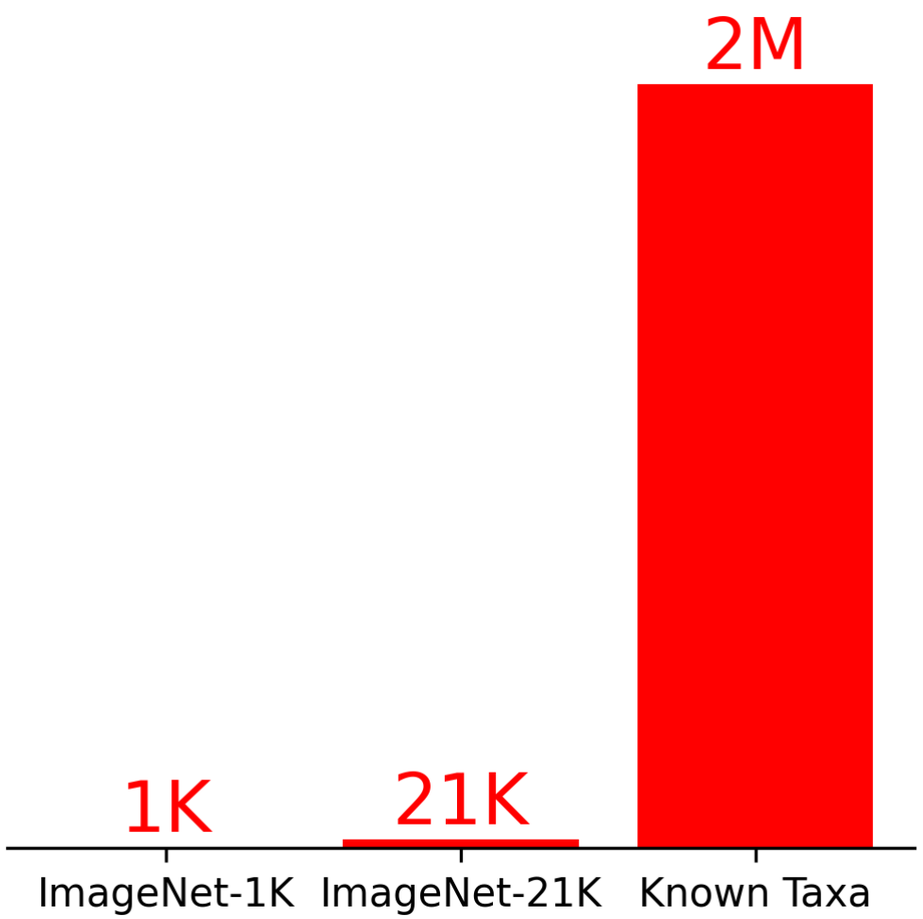

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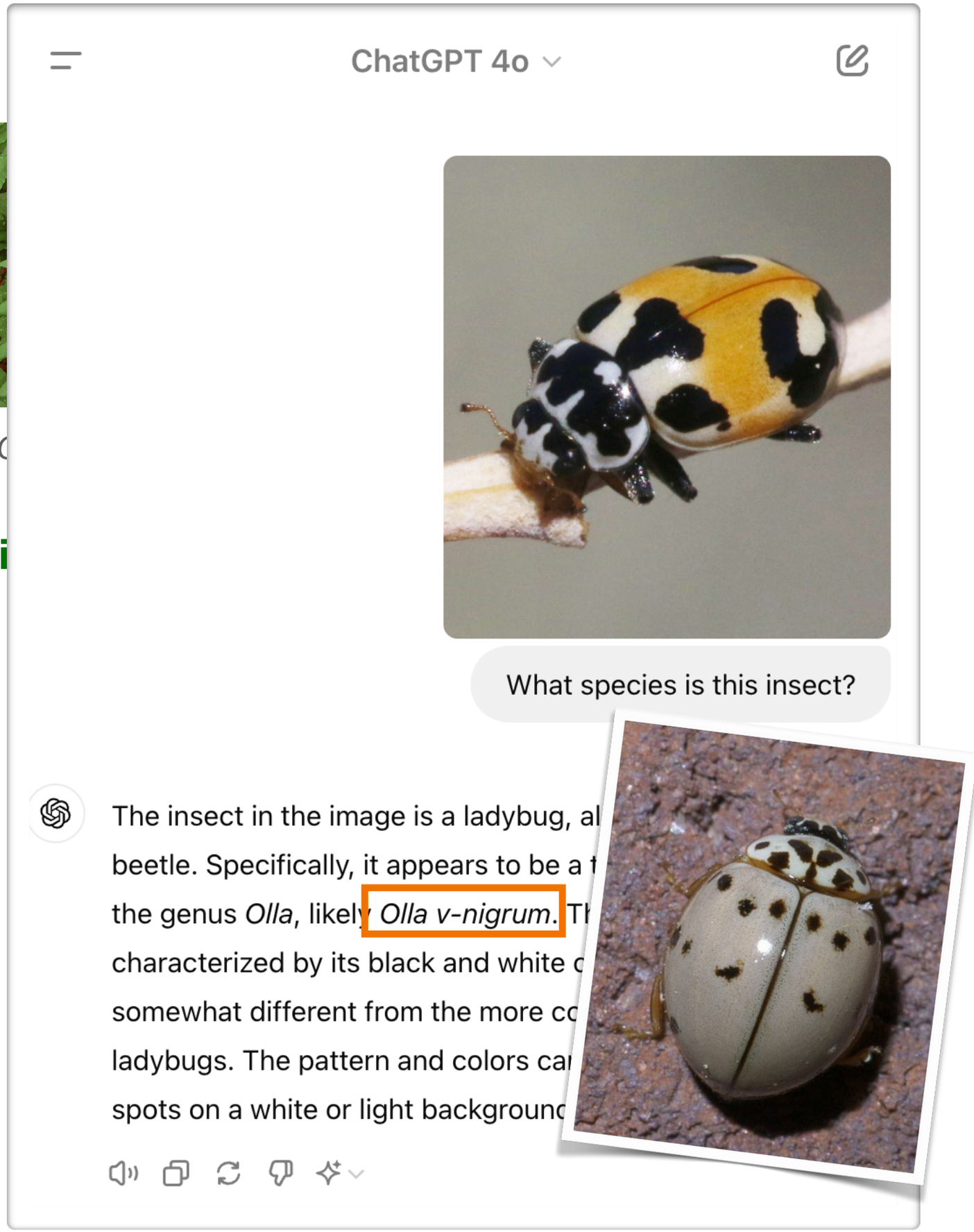

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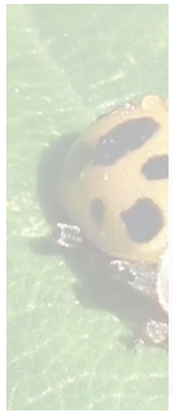
Hippodamia apicalis



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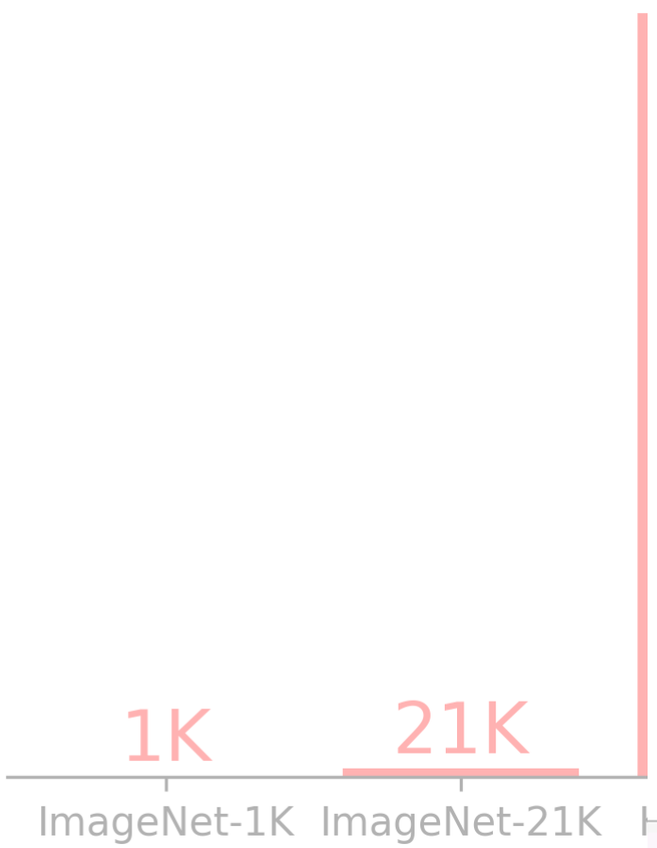

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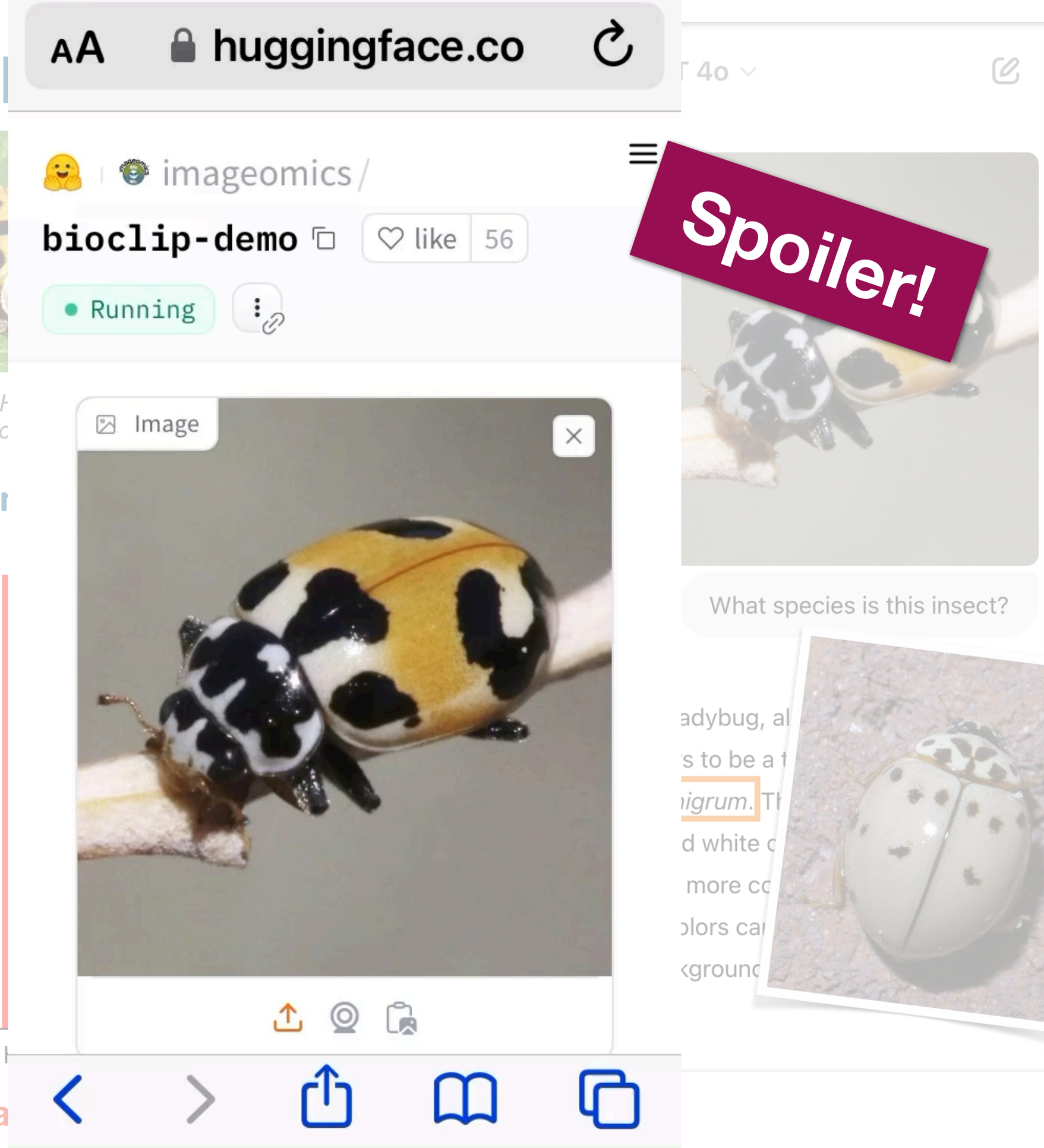

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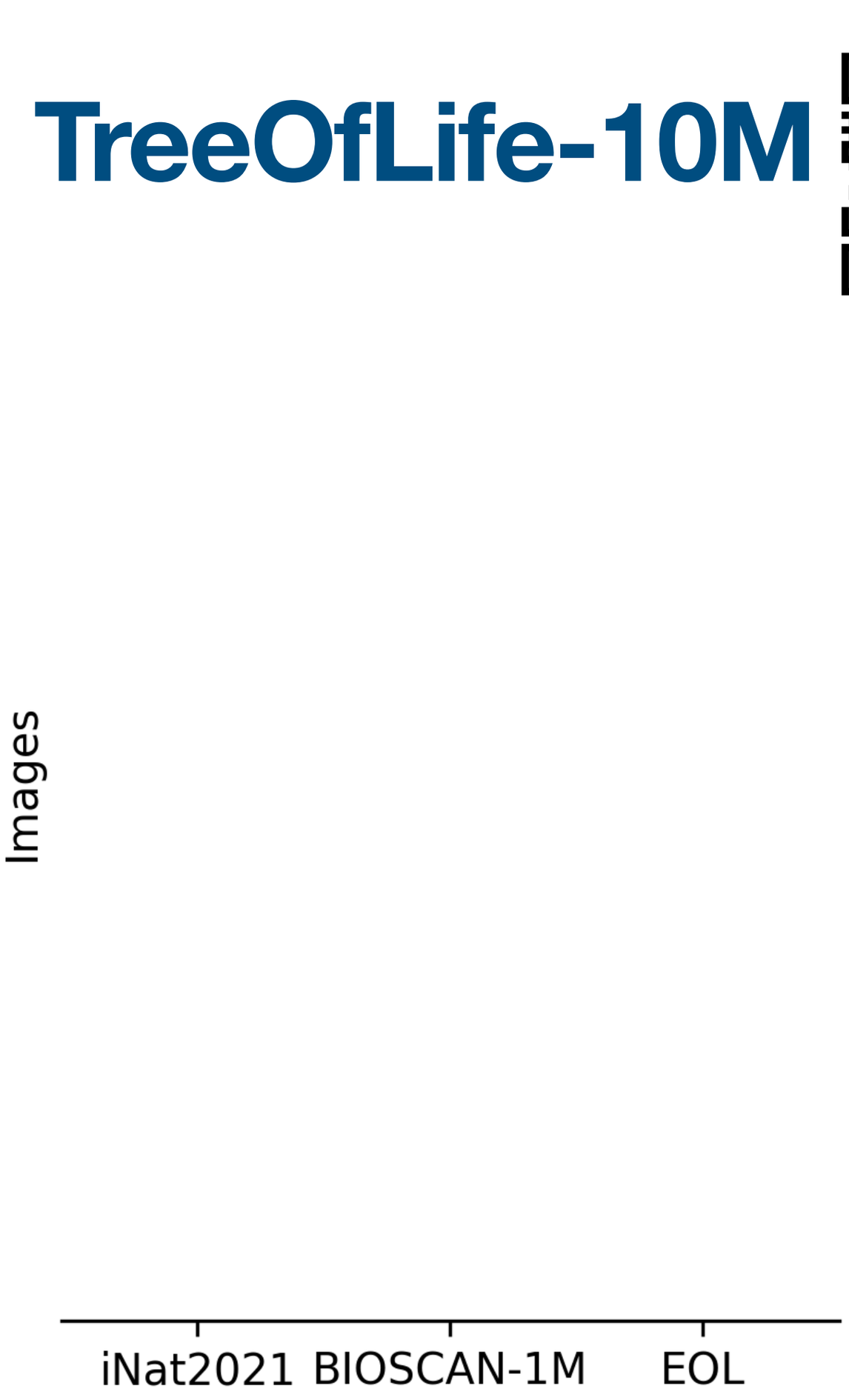

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Images

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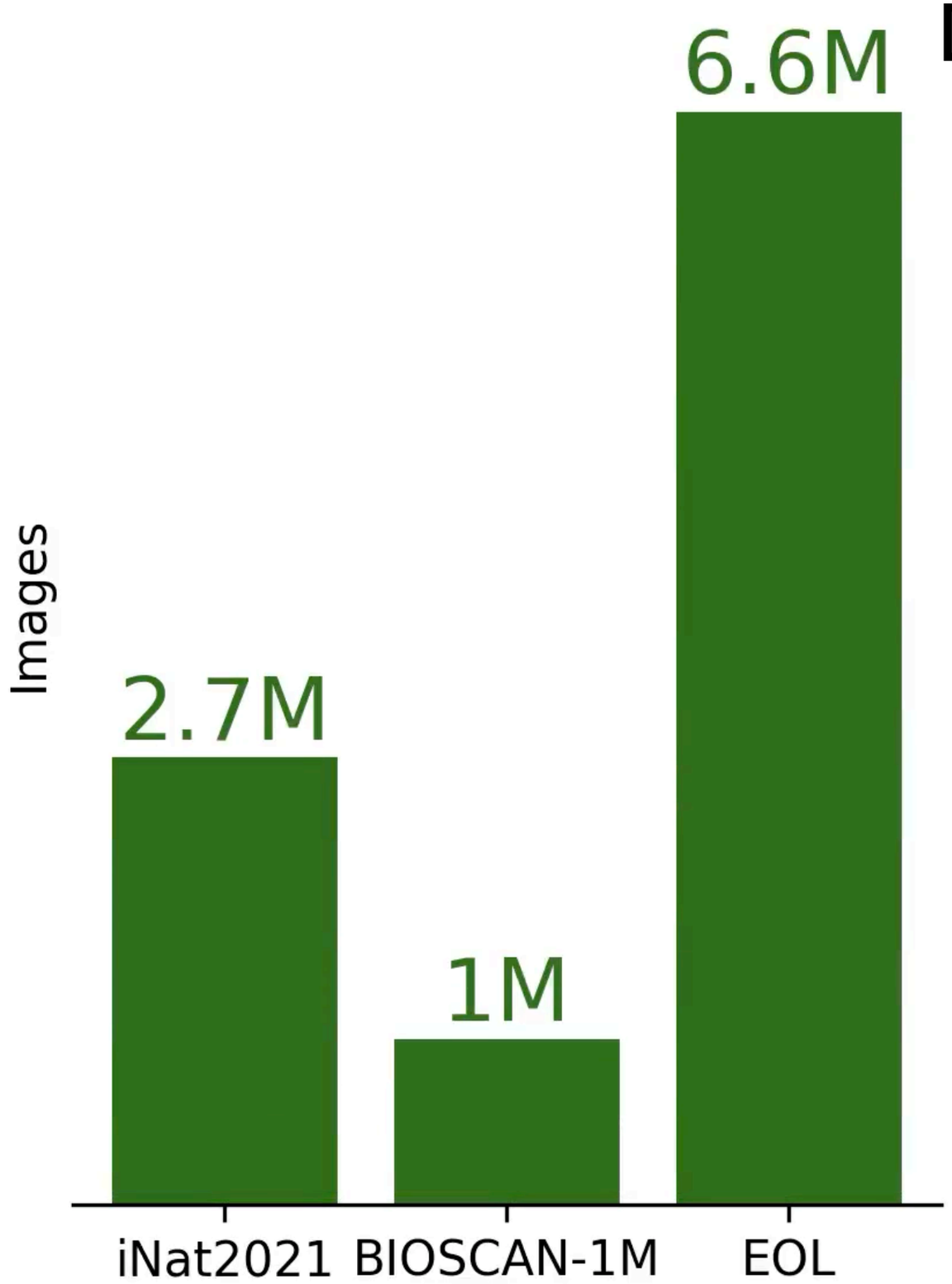

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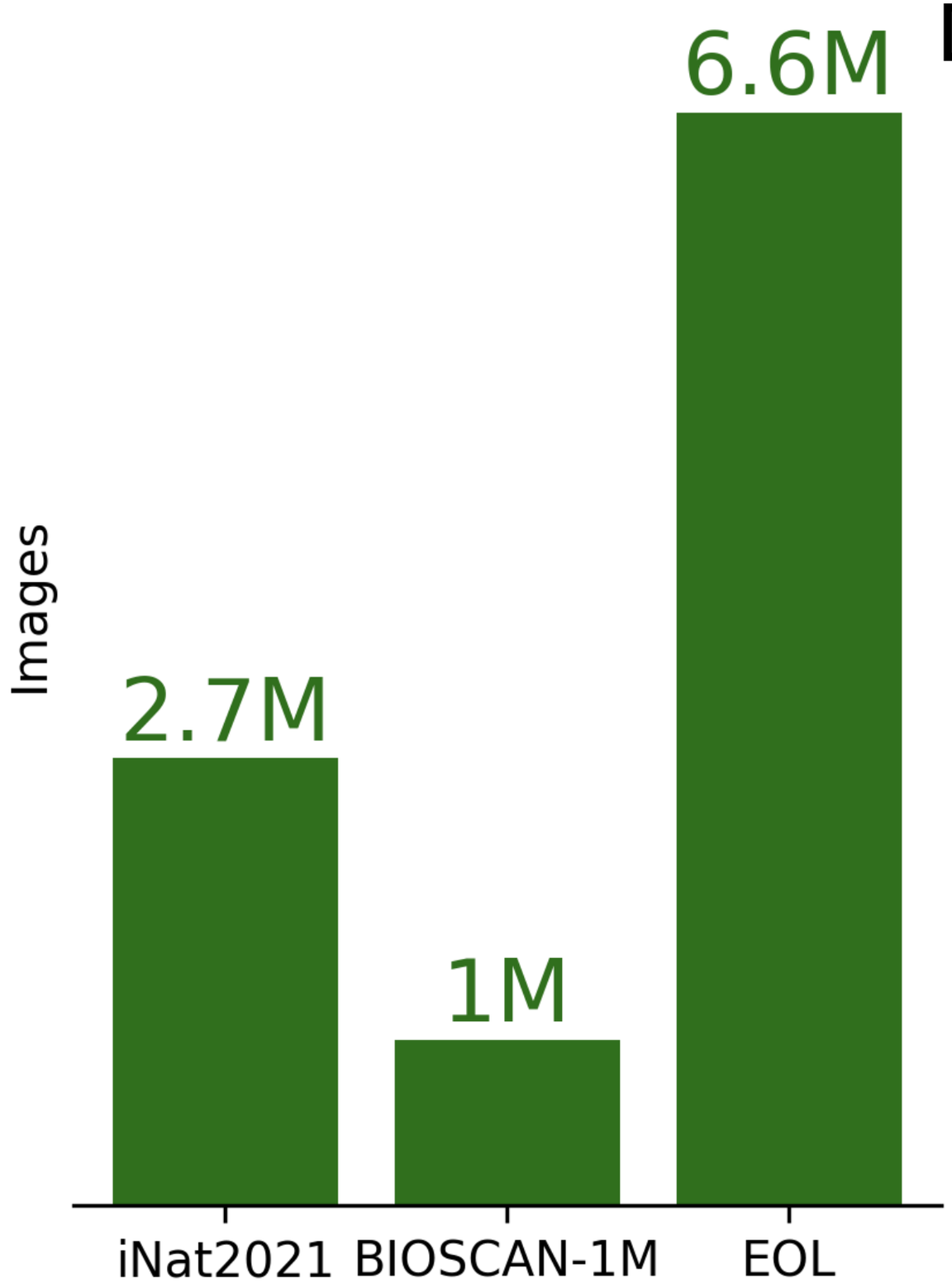

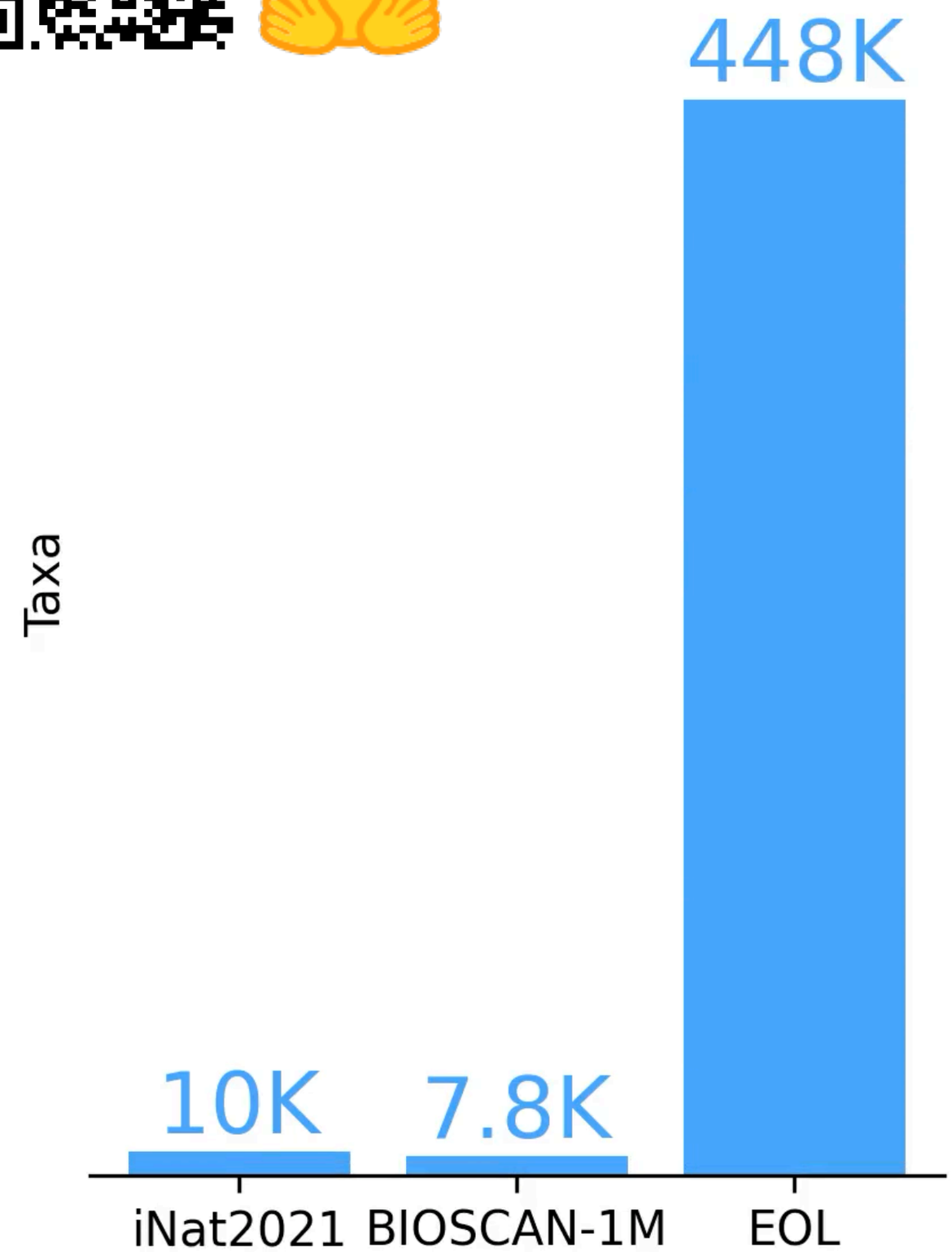

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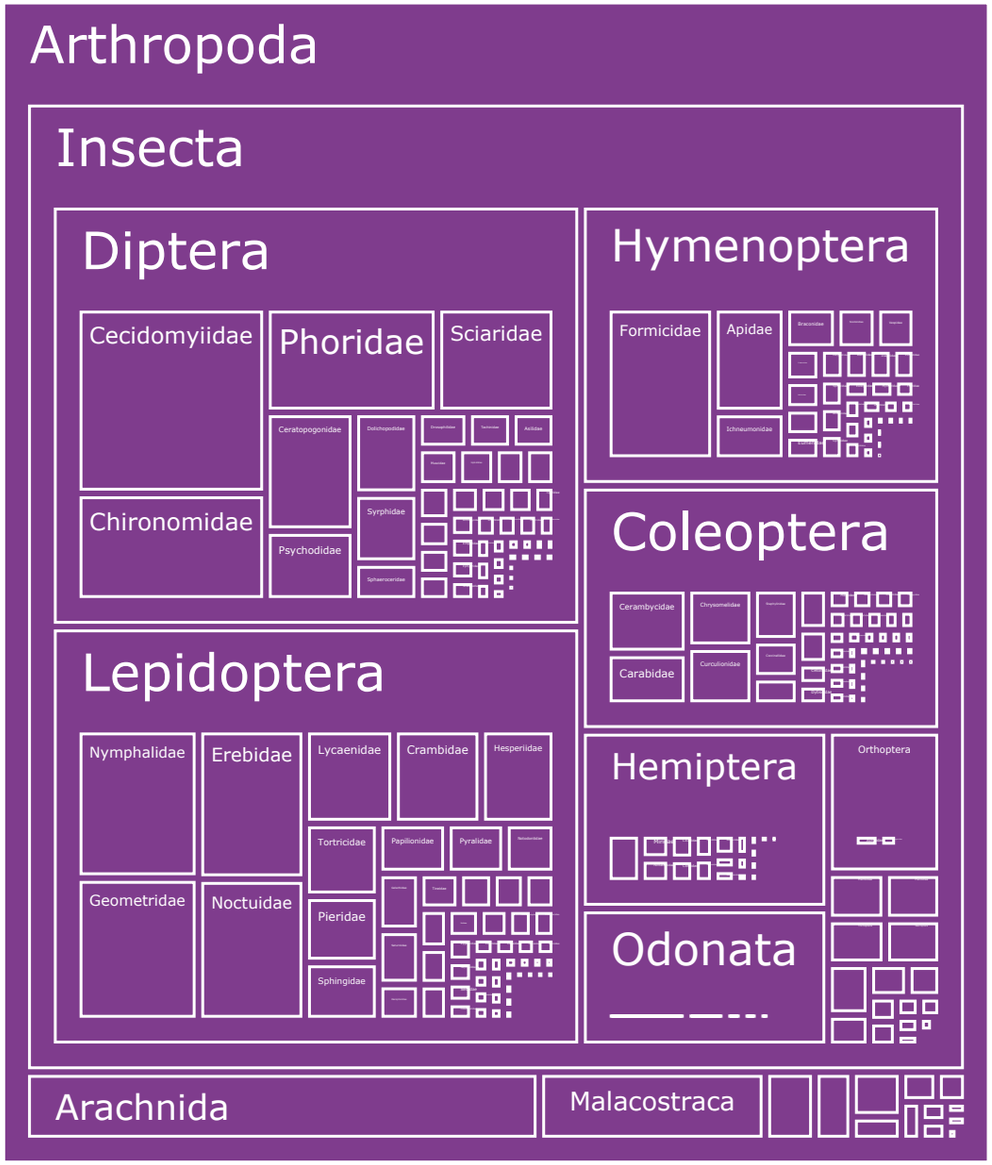

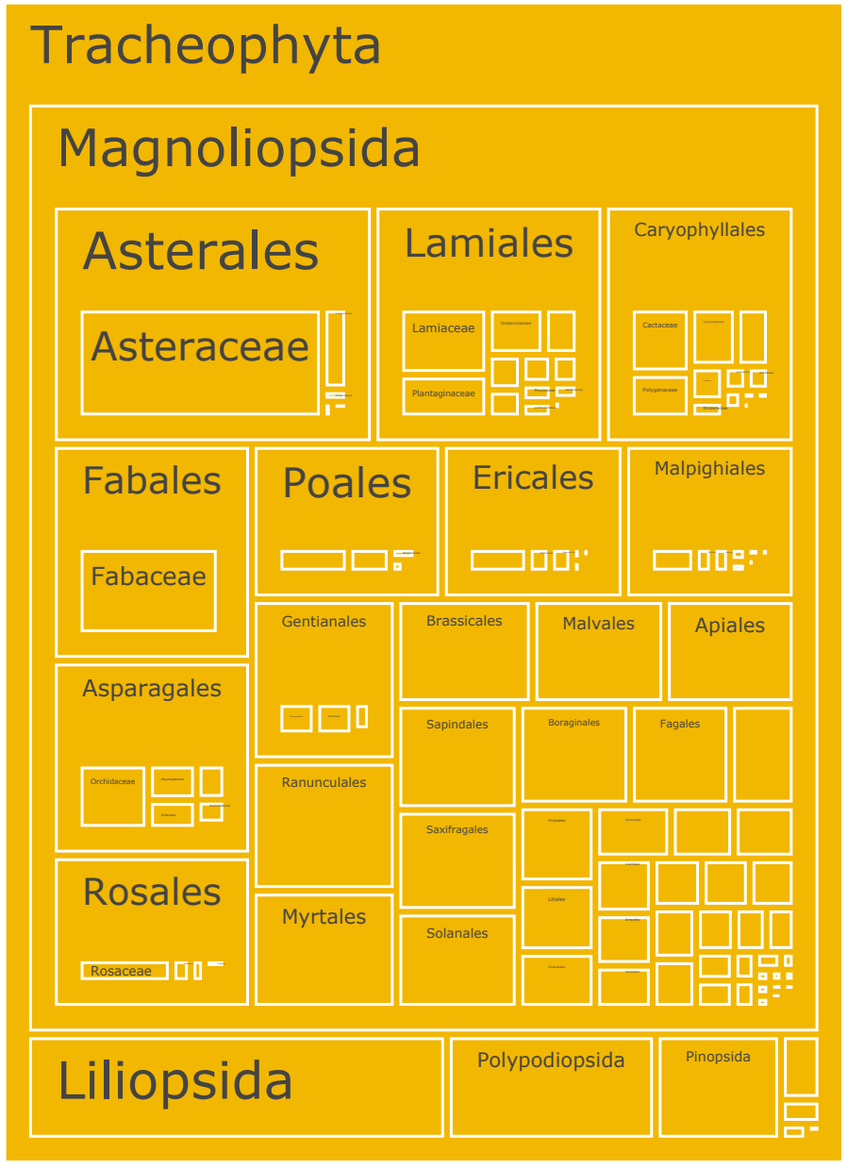

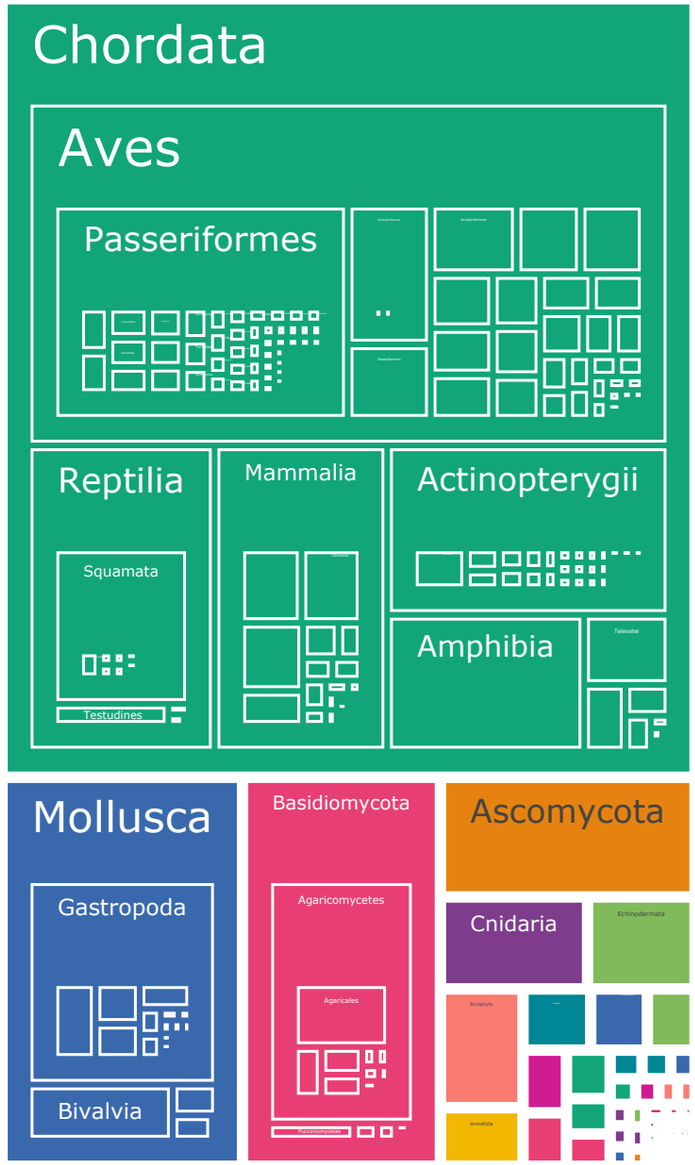

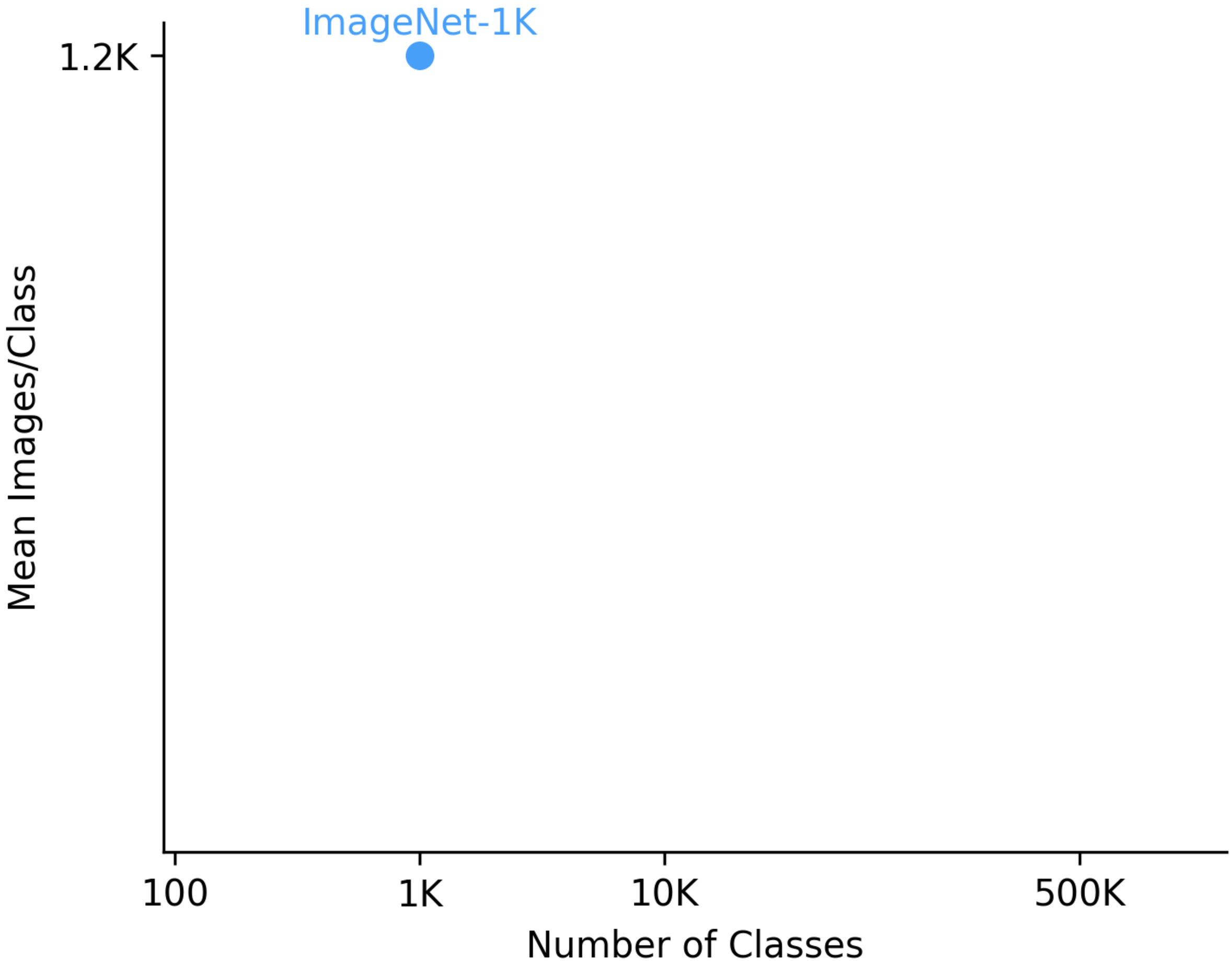
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Mean Images/Class
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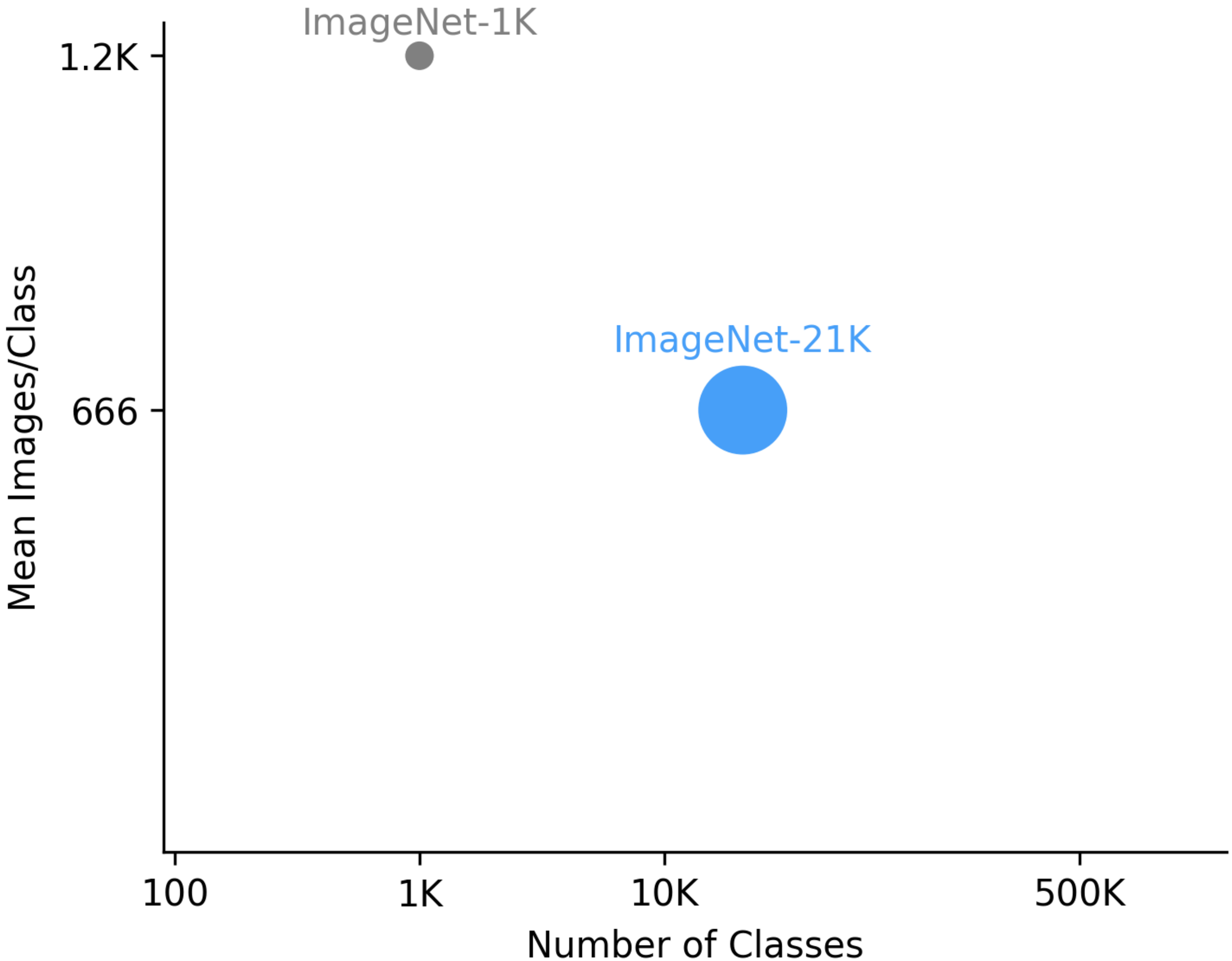
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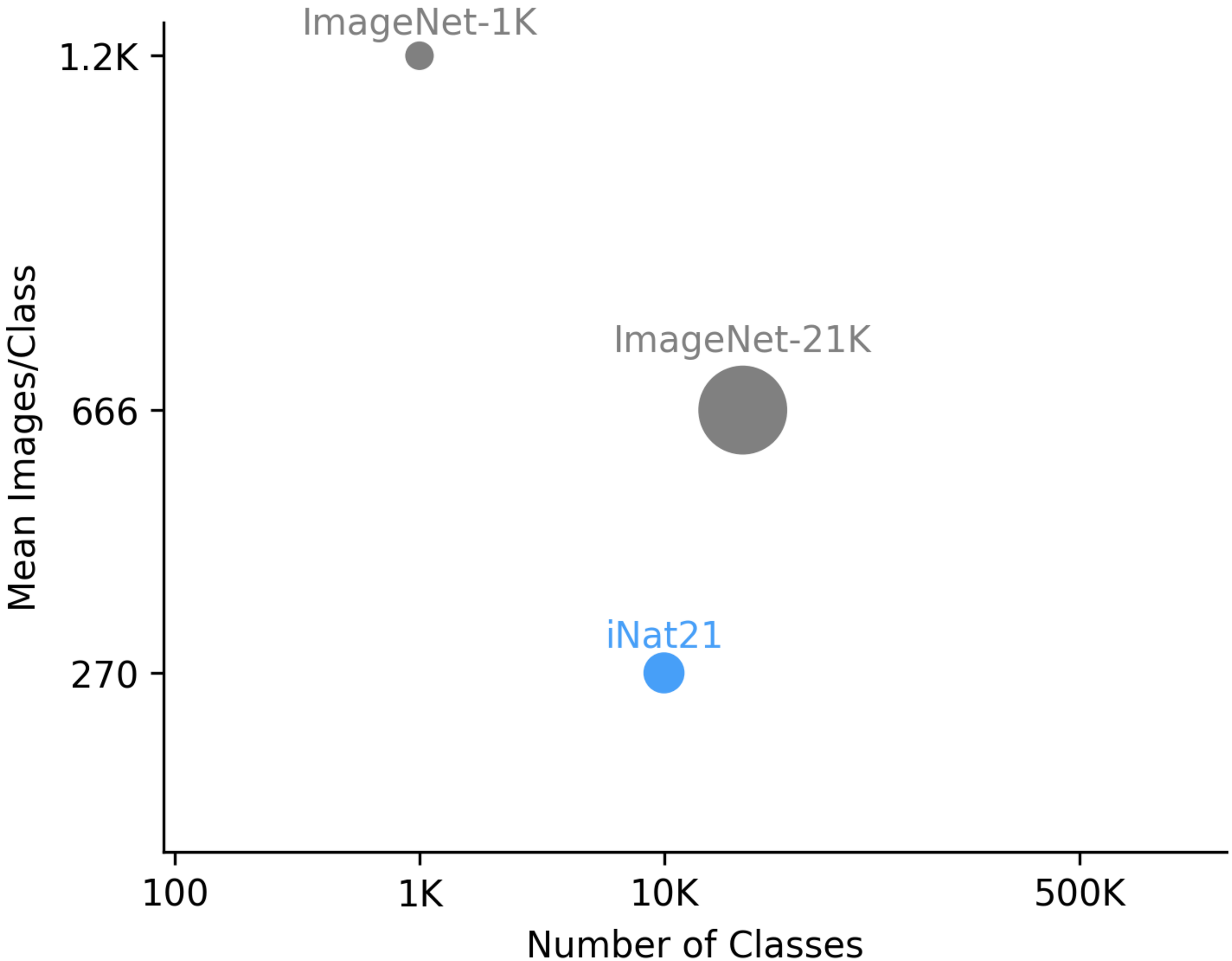
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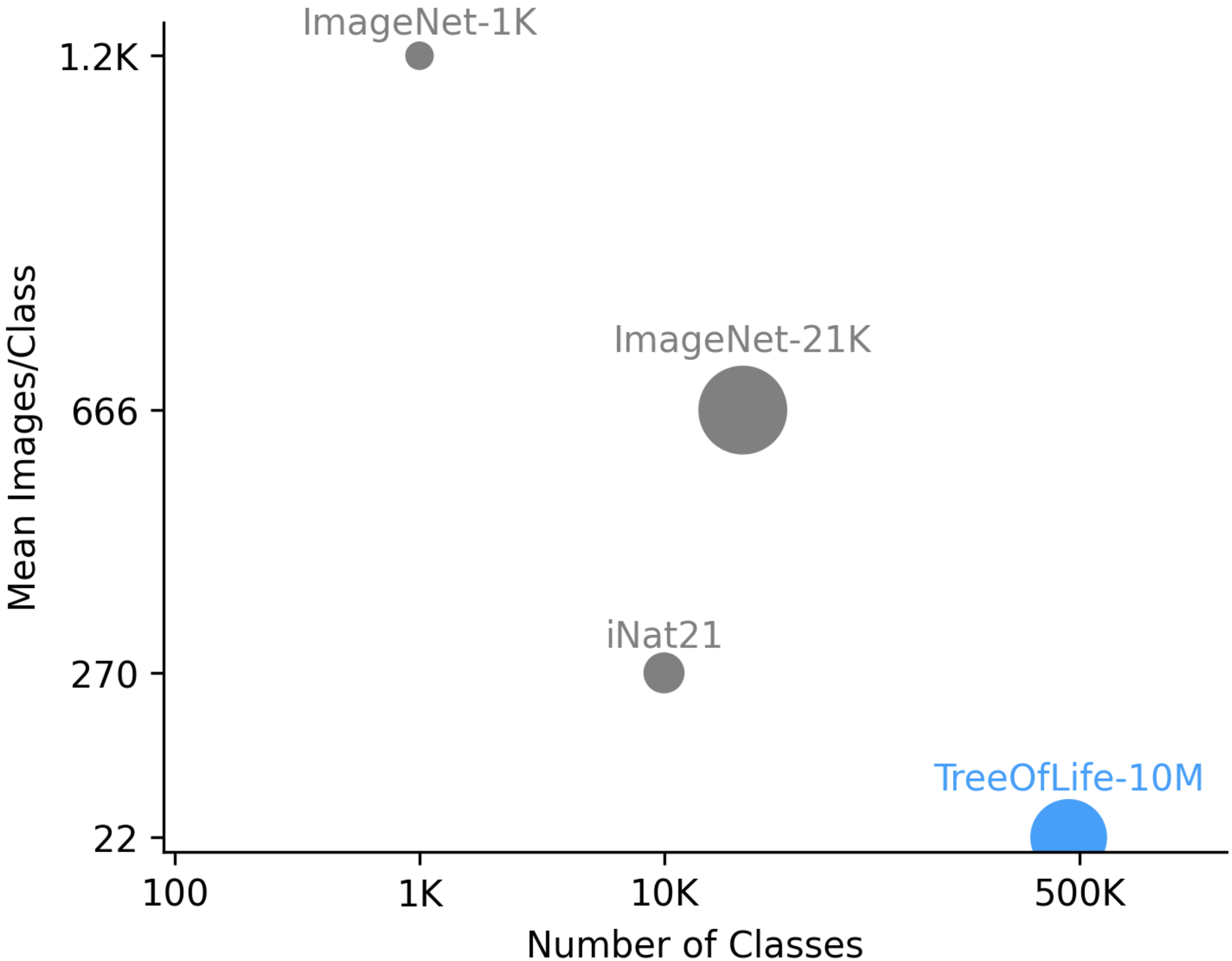
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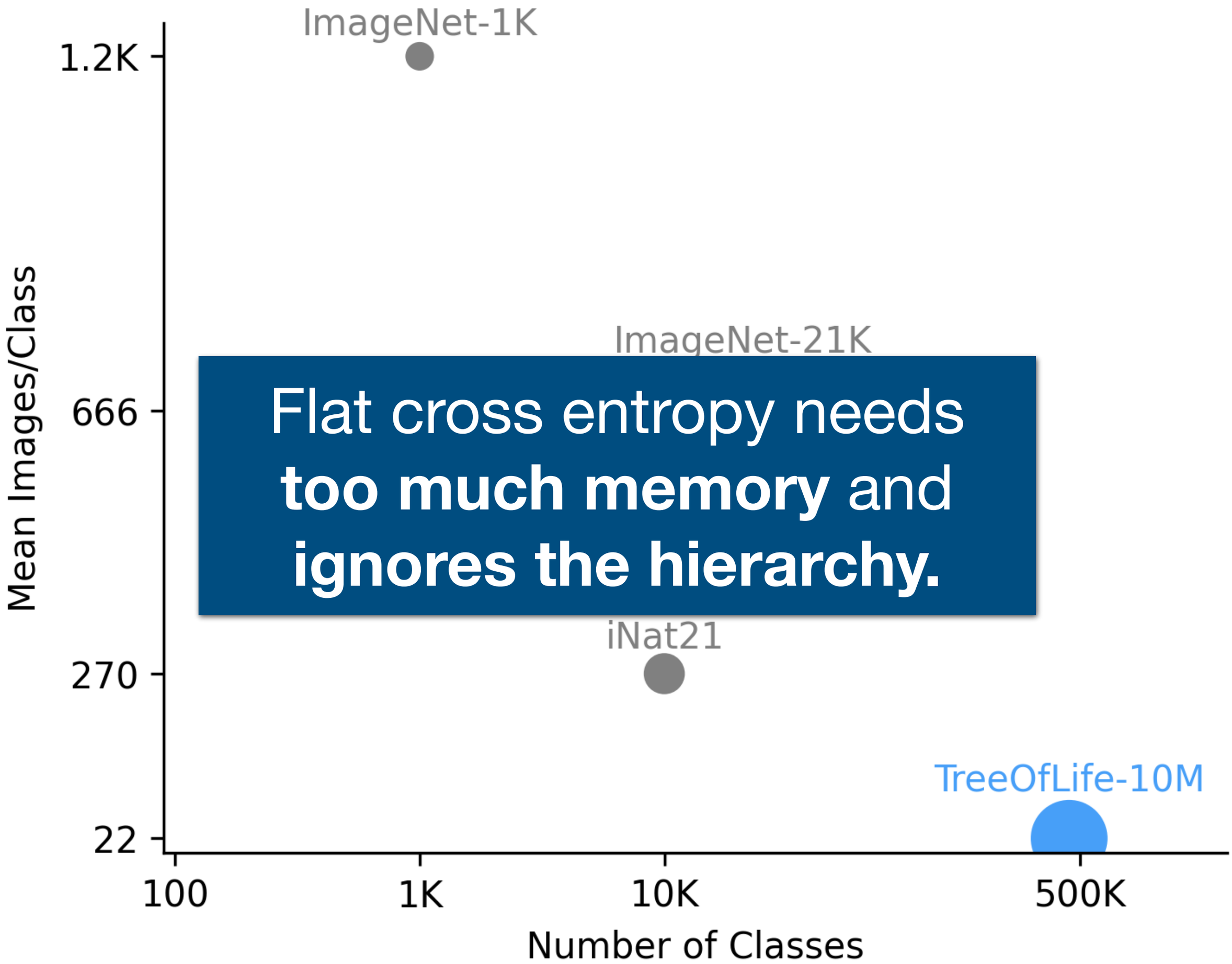

Flat cross entropy needs **too much memory** and **ignores the hierarchy.**

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Sage Green Deep Purple Polka Dot Pillowcase Dress

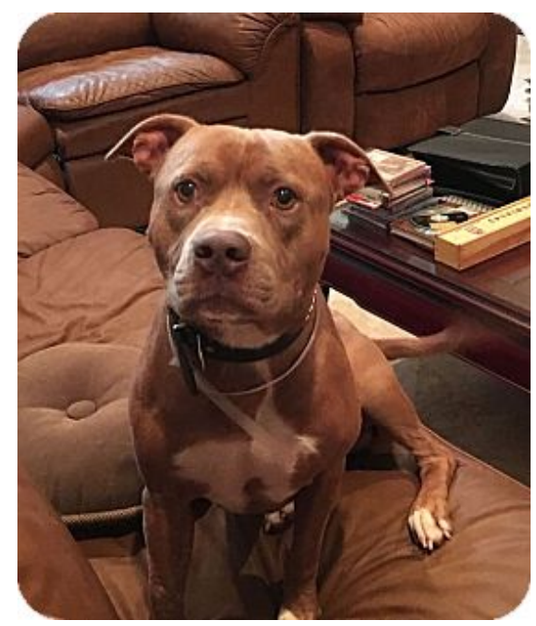
Greater Swiss Mountain Dog Ears

Girl stands at baby gate in doorway

Chinese Dragon Dog T-Shirt

Harry Potter Studio, London

Maltese/Poodle (Miniature) Mix Dog for adoption in Woodland Hills, California



American Staffordshire Terrier/American Bulldog Mix Dog for adoption in Miami, Florida

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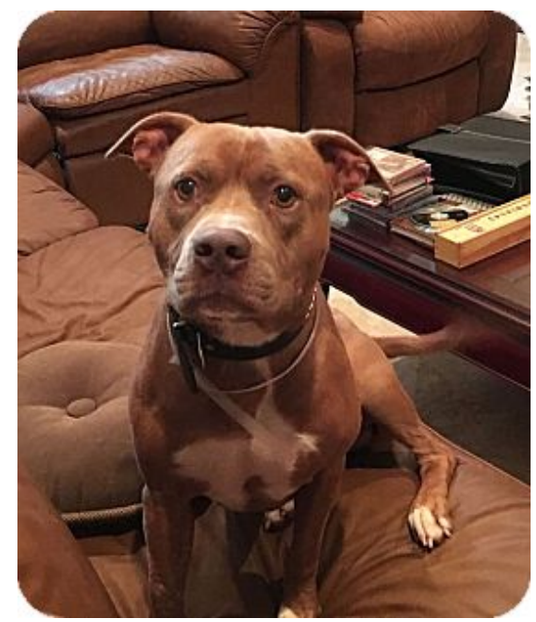

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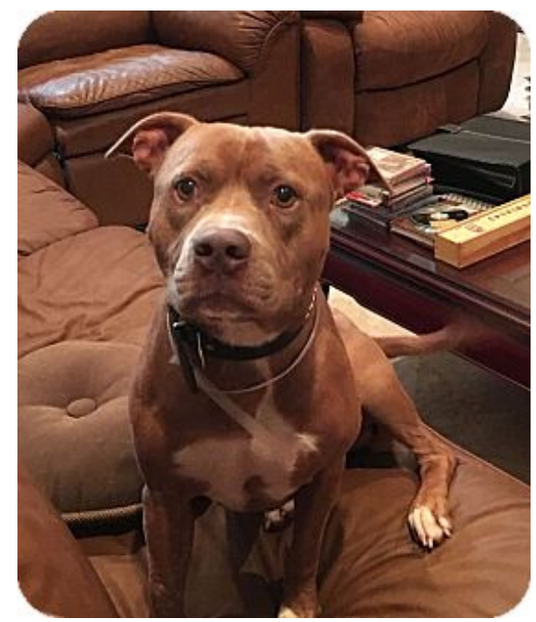

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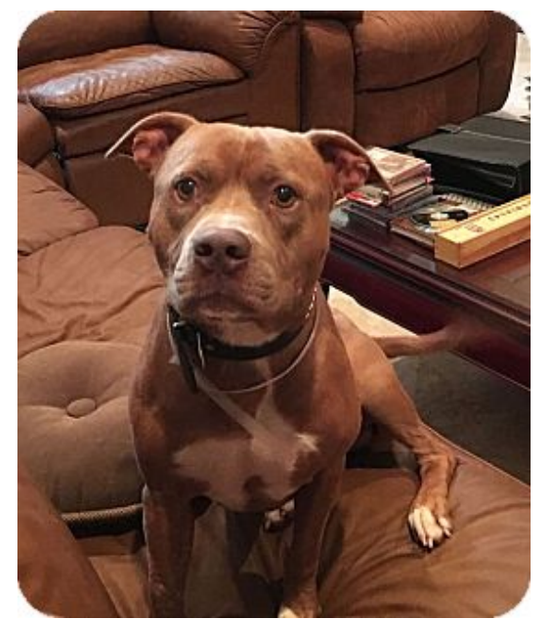

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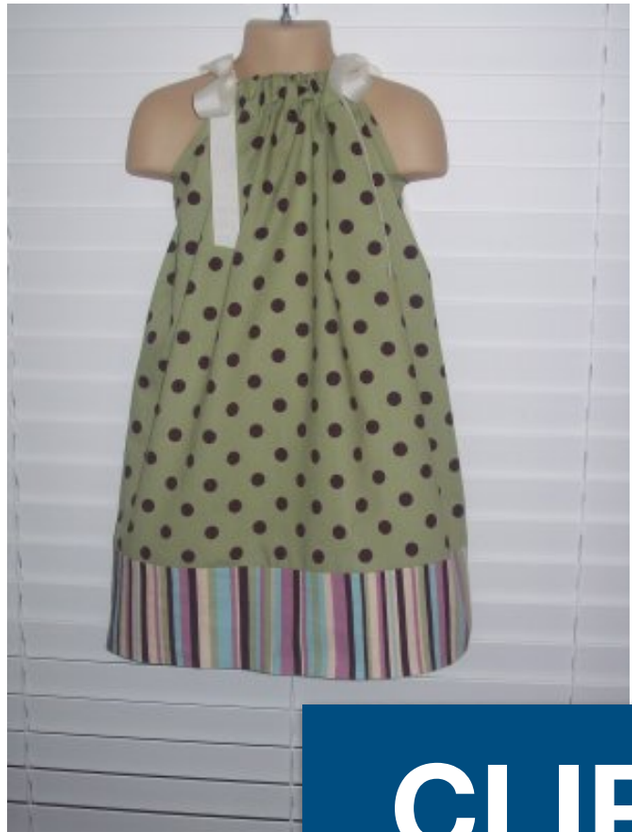

Sage Green Polka Dot Dr

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CLIP learns from repeated structures in class labels.

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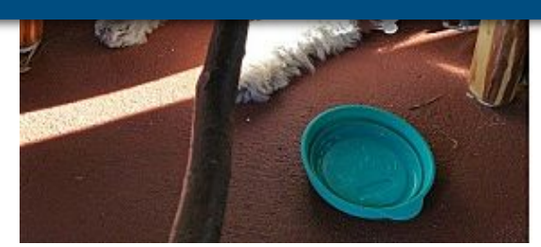

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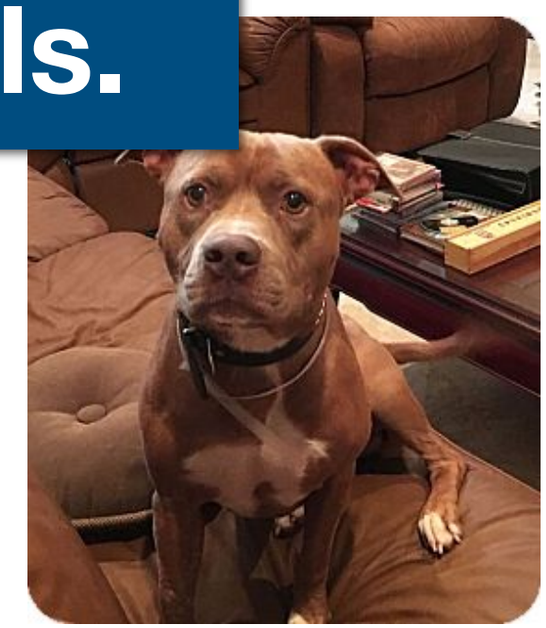

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Animalia Arthropoda Insecta
Lepidoptera Heliozelidae
Antispila treitschkiella

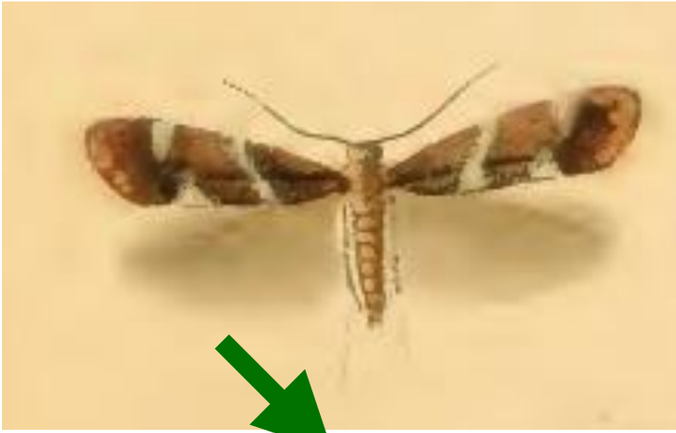
Animalia Arthropoda Insecta
Lepidoptera Notodontidae
Pheraspis mesotypa

Plantae Tracheophyta
Magnoliopsida Arecales
Arecaceae Roystonea regia

Plantae Tracheophyta
Polypodiopsida Polypodiales
Athyriaceae Diplazium esculentum

Animalia Chordata Aves
Accipitriformes Accipitridae
Aquila spilogaster

Animalia Arthropoda Arachnida
Scorpiones Scorpionidae
Diplocentrus maya



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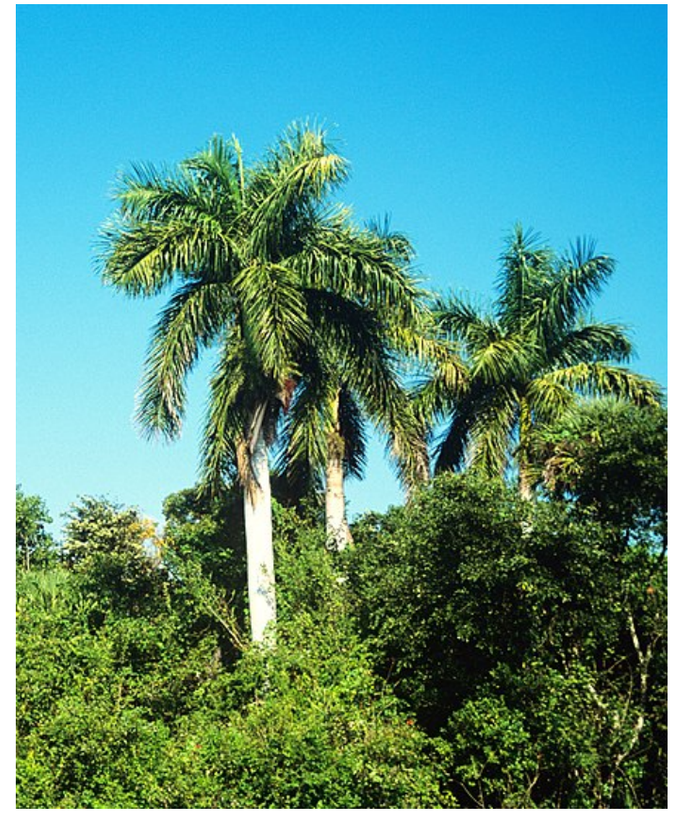

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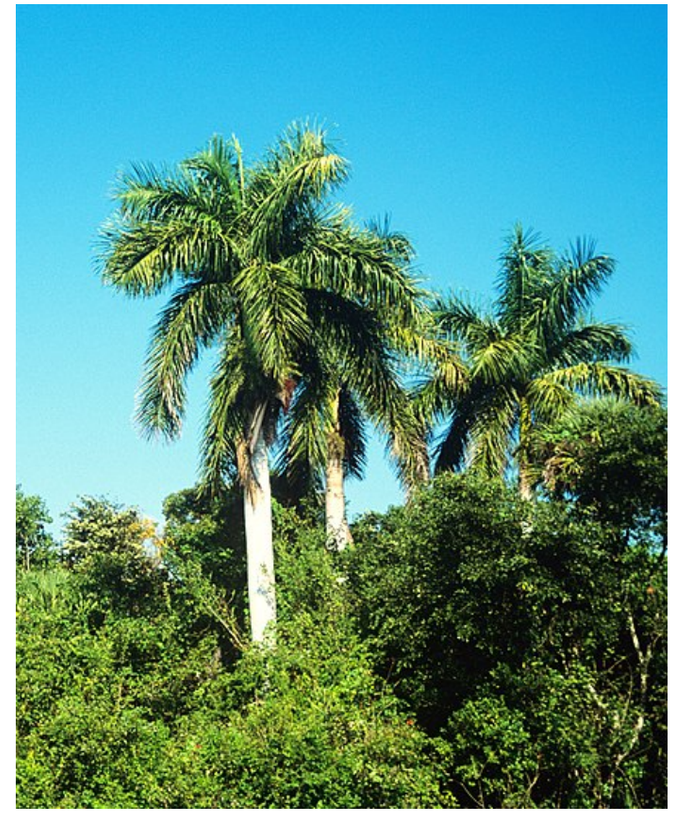

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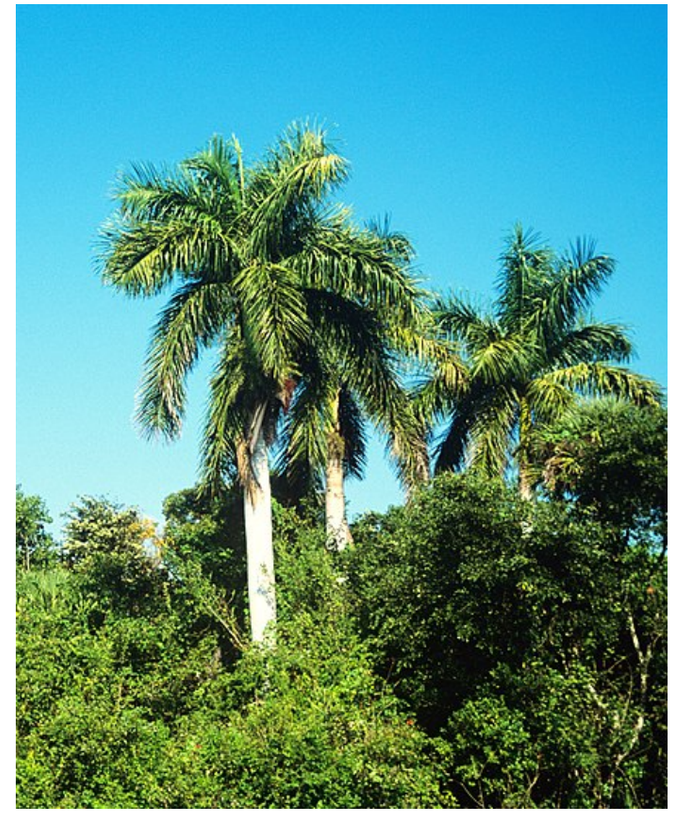

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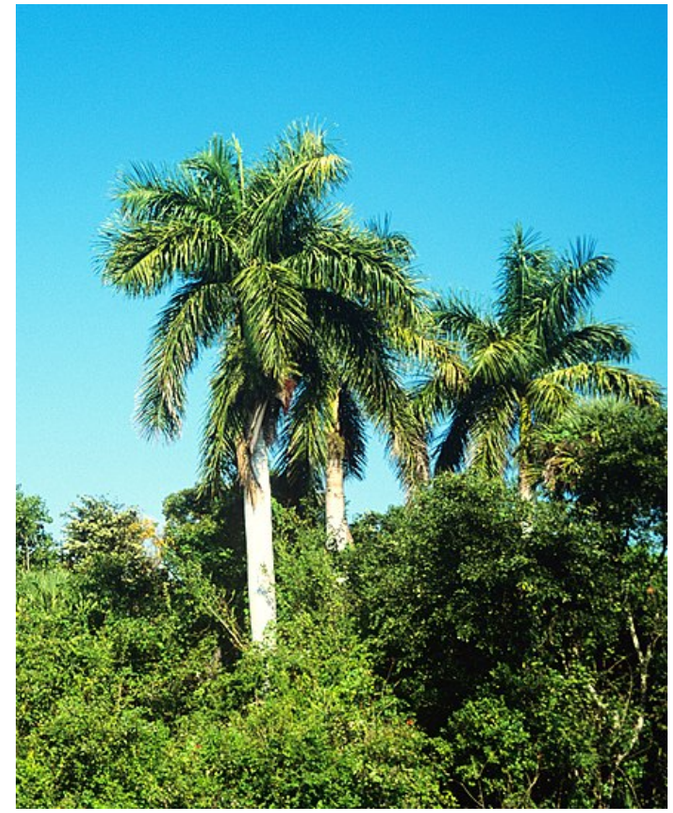

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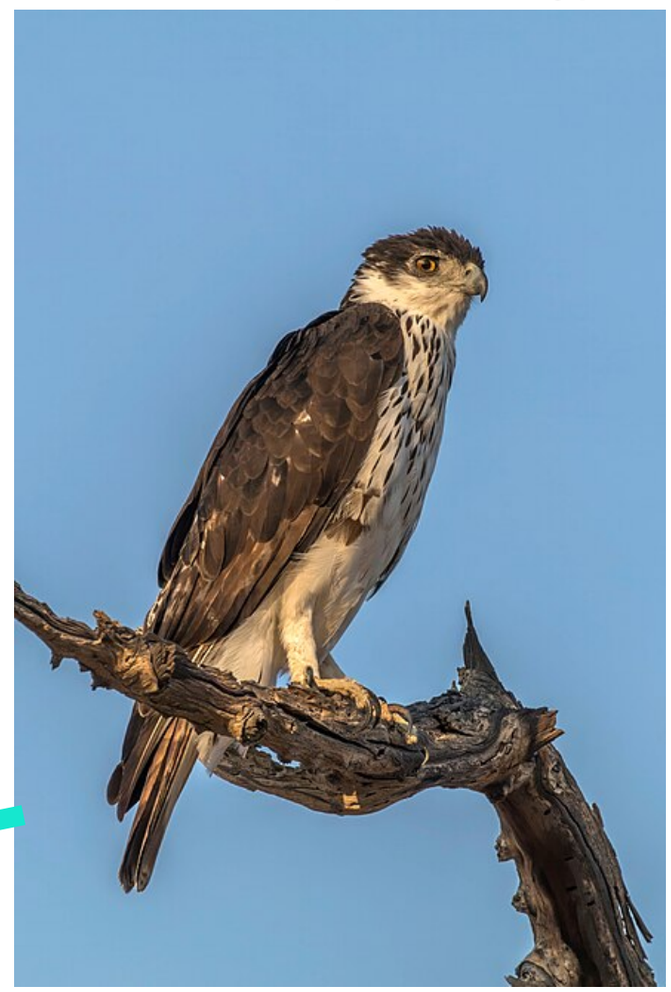

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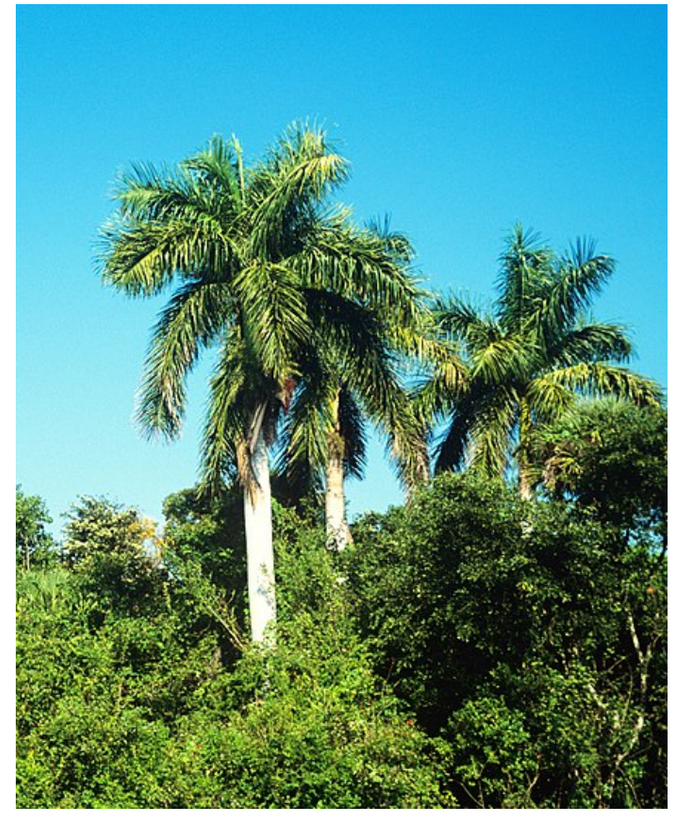
Accipitriformes Accipitridae
Aquila spilogaster

Animalia **Arthropoda** Arachnida
Scorpiones Scorpionidae
Diplocentrus maya

Animalia **Arthropoda** Insecta
Lepidoptera Heliozelidae
Antispila treitschkiella

Animalia **Arthropoda** Insecta
Lepidoptera Notodontidae
Pheraspis mesotypa



Plantae Tracheophyta
Magnoliopsida Arecales
Arecaceae Roystonea regia

Plantae Tracheophyta
Polypodiopsida Polypodiales
Athyriaceae Diplazium esculentum

Animalia Chordata Aves
Accipitriformes Accipitridae
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Animalia **Arthropoda** Arachnida
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CLIP learns from repeated structures in class labels.

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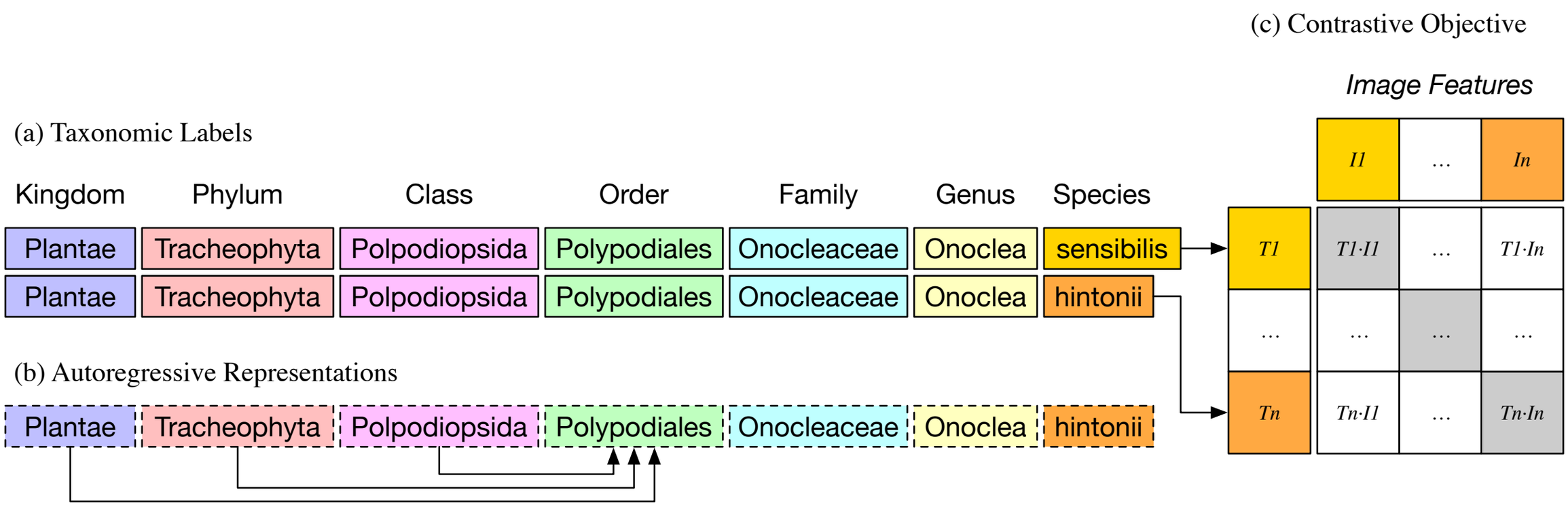
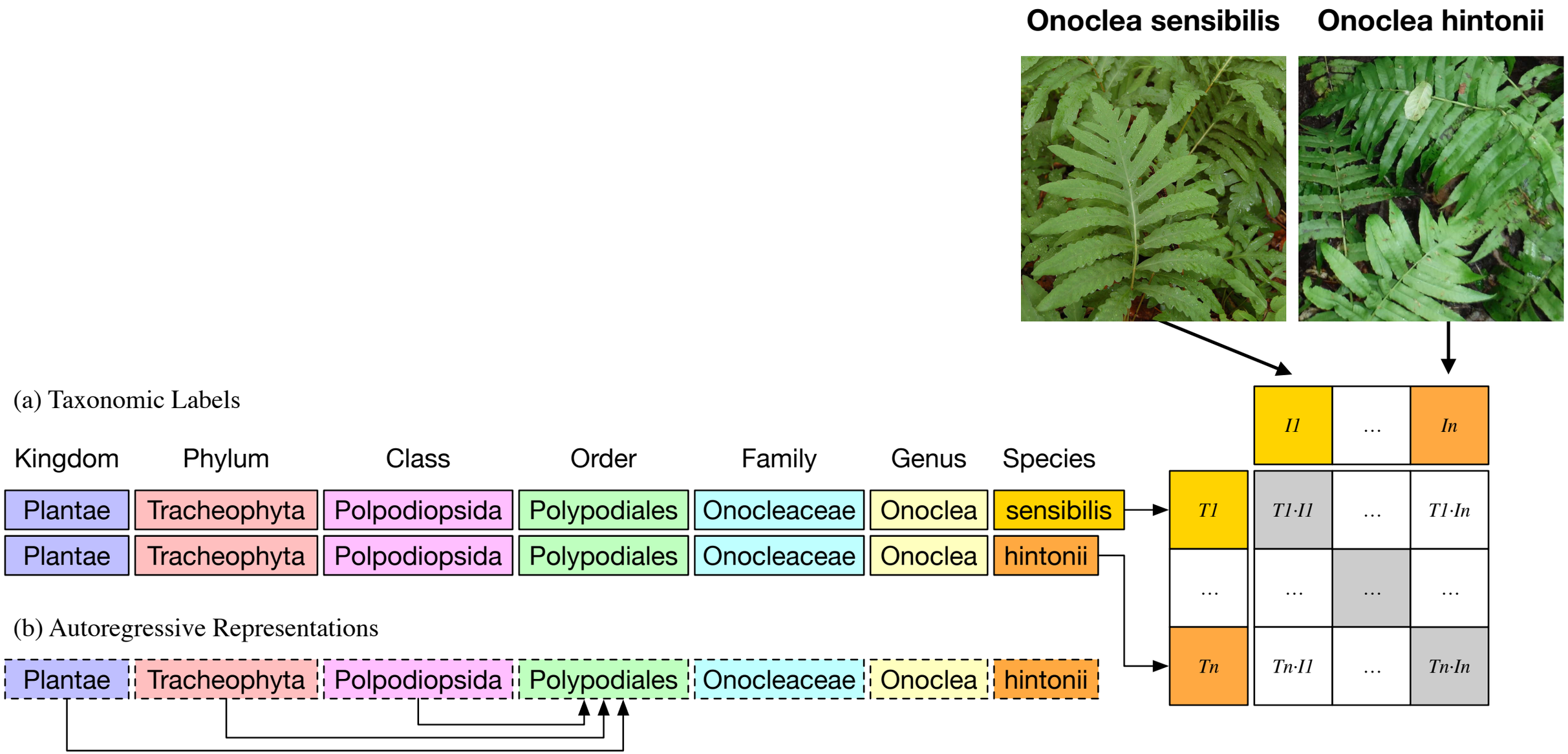
CLIP learns from repeated structures in class labels.

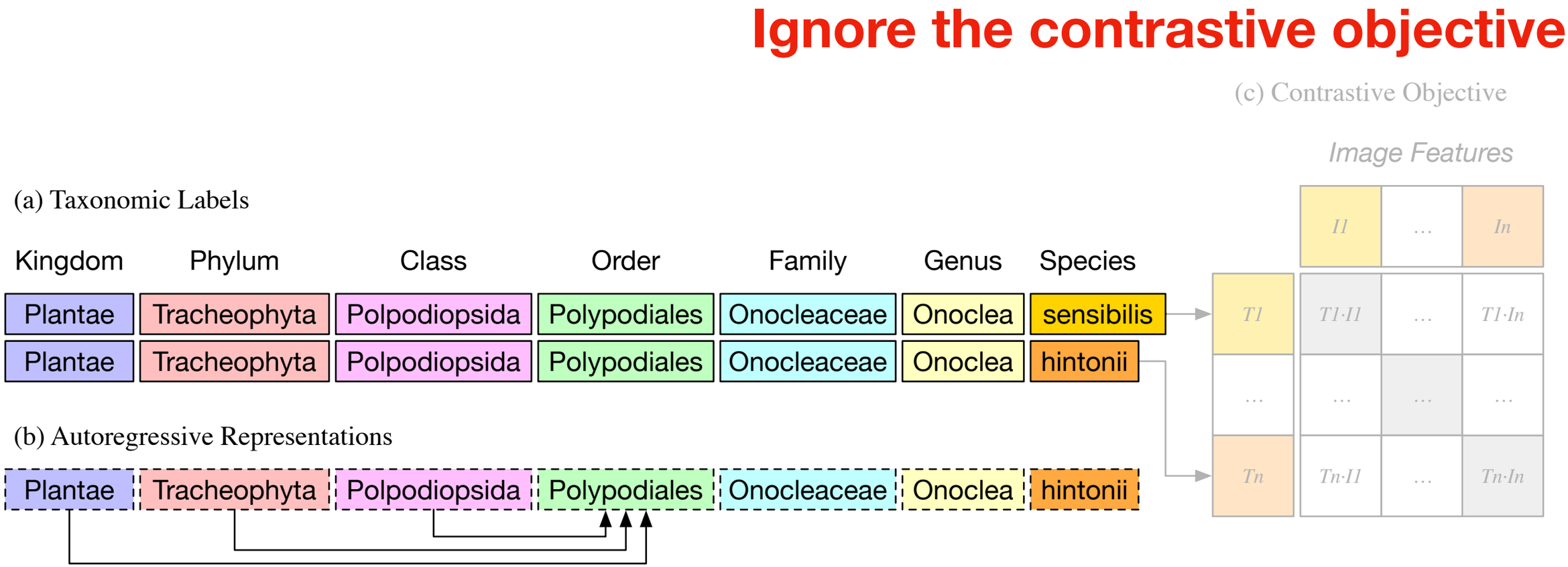
CLIP learns from repeated structures in class labels.



…and an autoregressive text encoder preserves hierarchical structure.

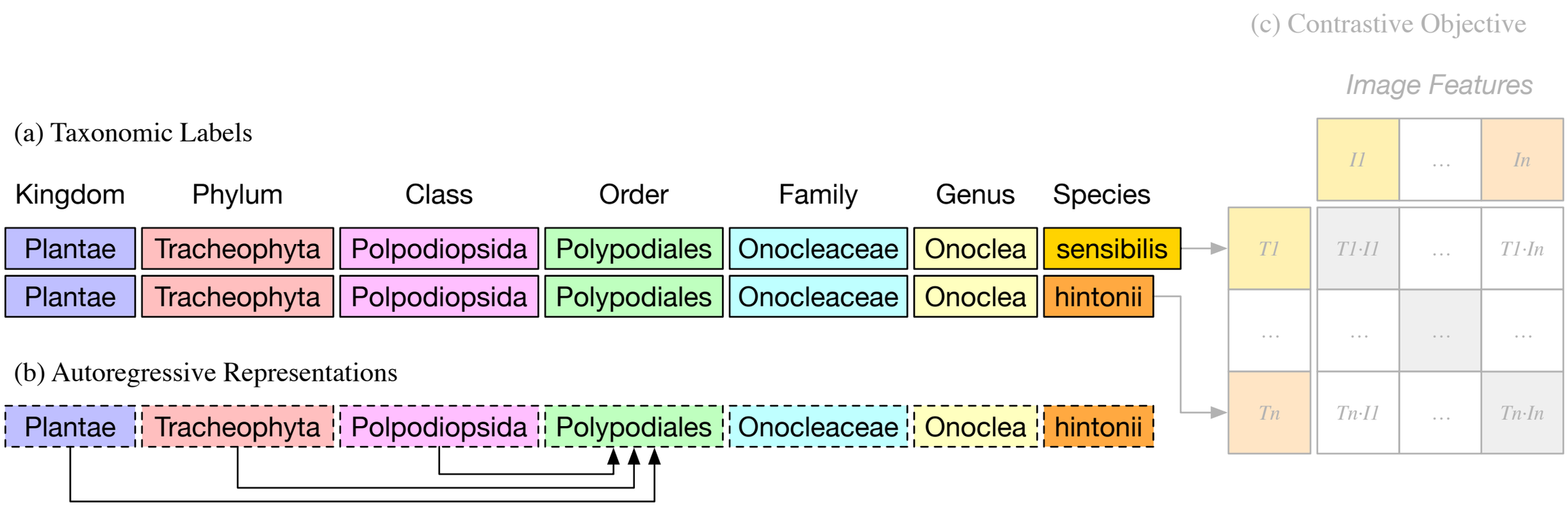

Onoclea sensibilis
Onoclea hintonii
(a) Taxonomic Labels
Kingdom
Phylum
Class
Order
Family
Genus
Species
Plantae
Tracheophyta
Polpodiopsida
Polypodiales
Onocleaceae
Onoclea
sensibilis
Plantae
Tracheophyta
Polpodiopsida
Polypodiales
Onocleaceae
Onoclea
hintonii
I1
…
In
T1
T1·I1
…
T1·In
…
…
…
…
Tn
Tn·I1
…
Tn·In
(b) Autoregressive Representations
Plantae
Tracheophyta
Polpodiopsida
Polypodiales
Onocleaceae
Onoclea
hintonii

Ignore the contrastive objective.



Order

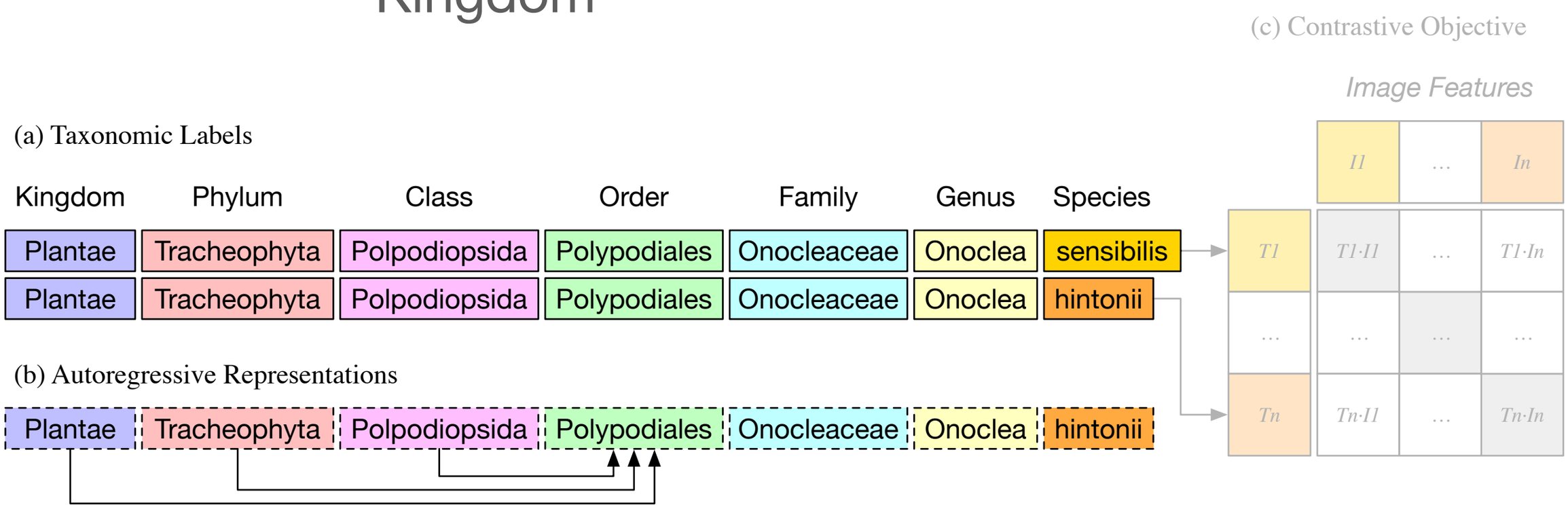
“Polypodiales” only conditions on higher taxonomic levels.



Order

“Polypodiales” only conditions on higher taxonomic levels.

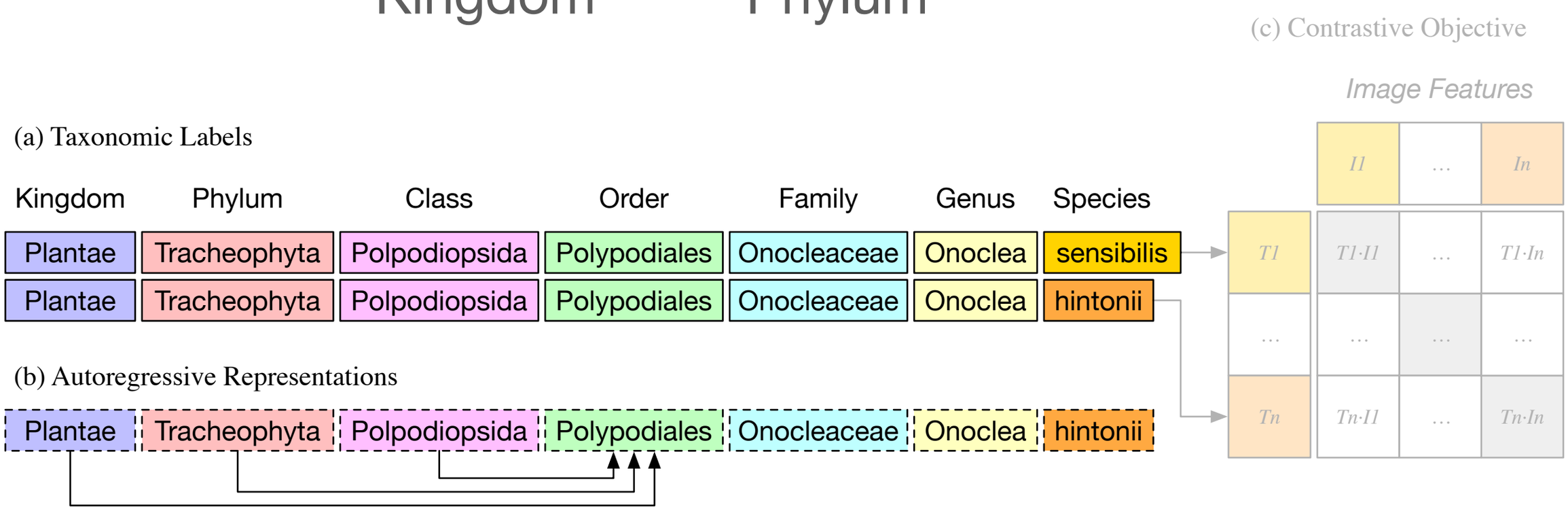
Kingdom



Order

“Polypodiales” only conditions on higher taxonomic levels.

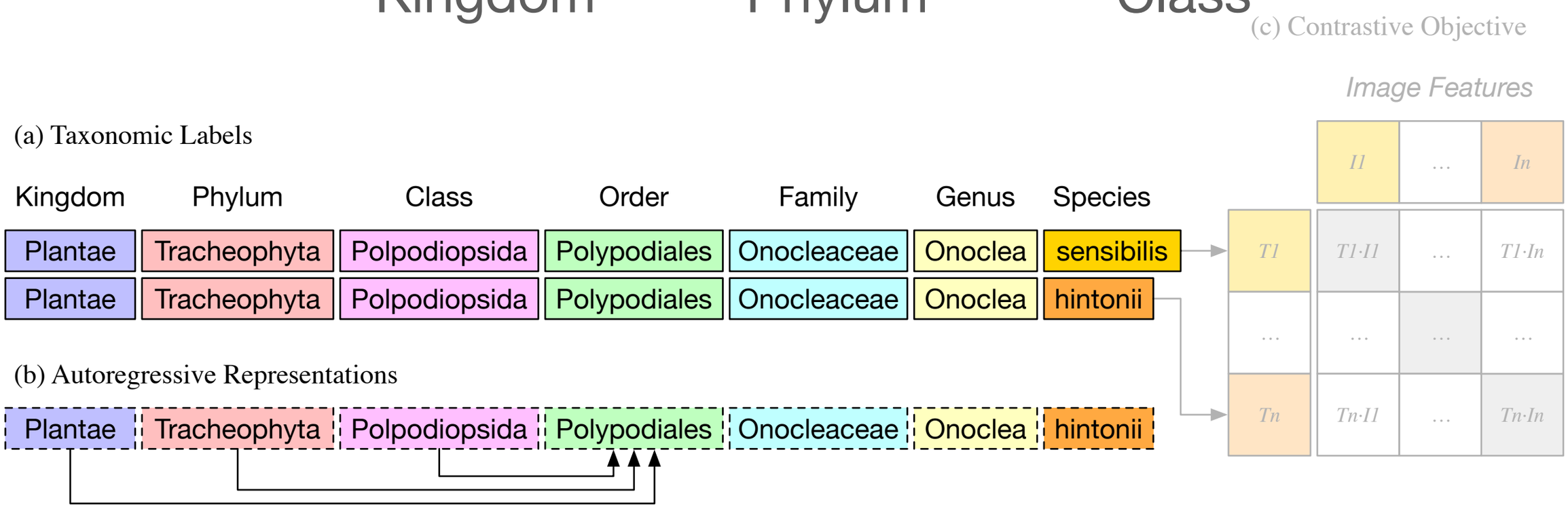
Kingdom Phylum



Order

“Polypodiales” only conditions on higher taxonomic levels.

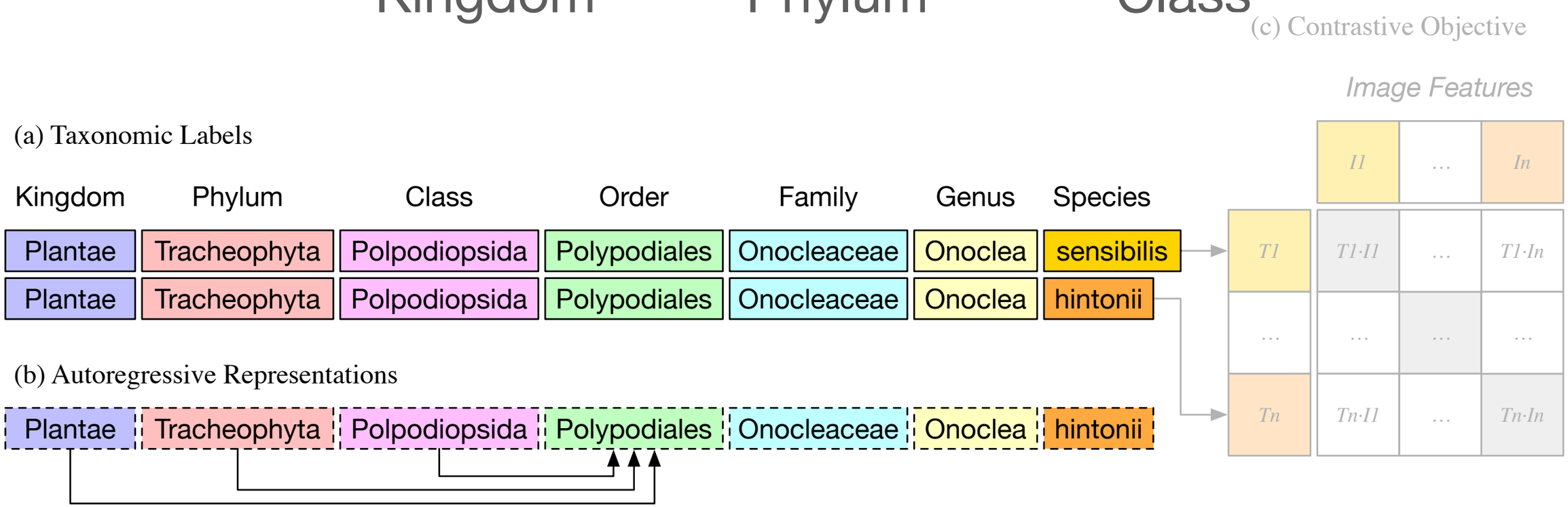
Kingdom Phylum Class



Order

“Polypodiales” only conditions on higher taxonomic levels.

Kingdom Phylum Class

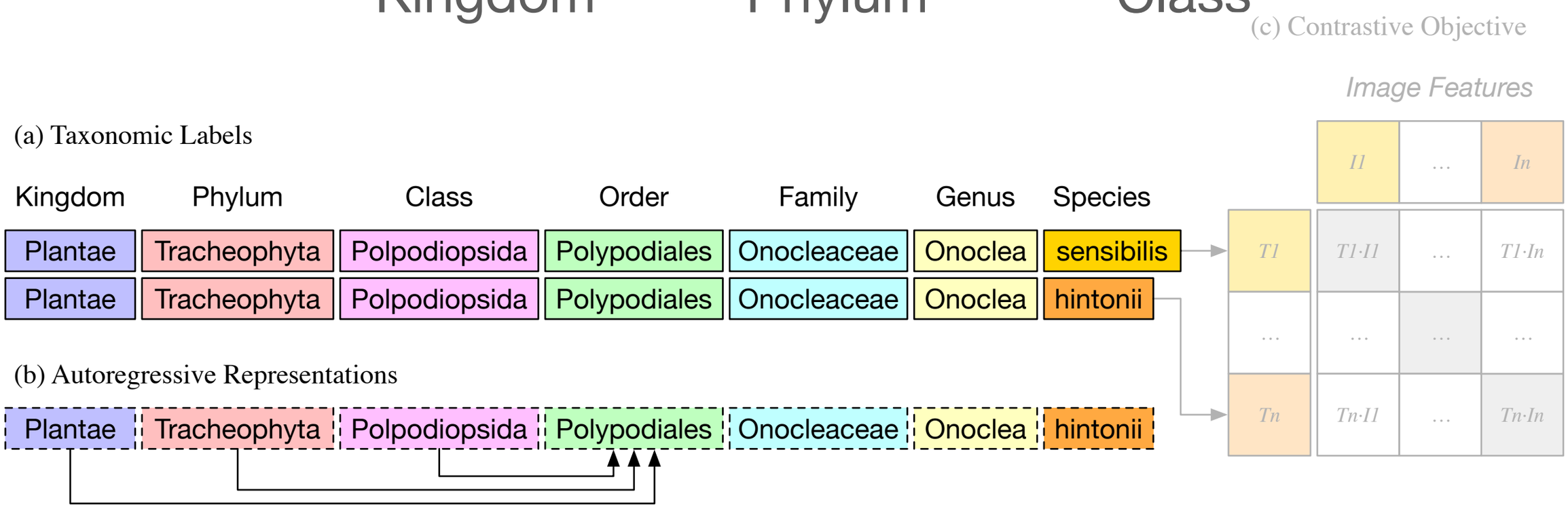


P(Polypodiales | Plantae Tracheophyta Popodiopsida)

Order

“Polypodiales” only conditions on higher taxonomic levels.

Kingdom Phylum Class



P(Polypodiales | Plantae Tracheophyta Popodiopsida)

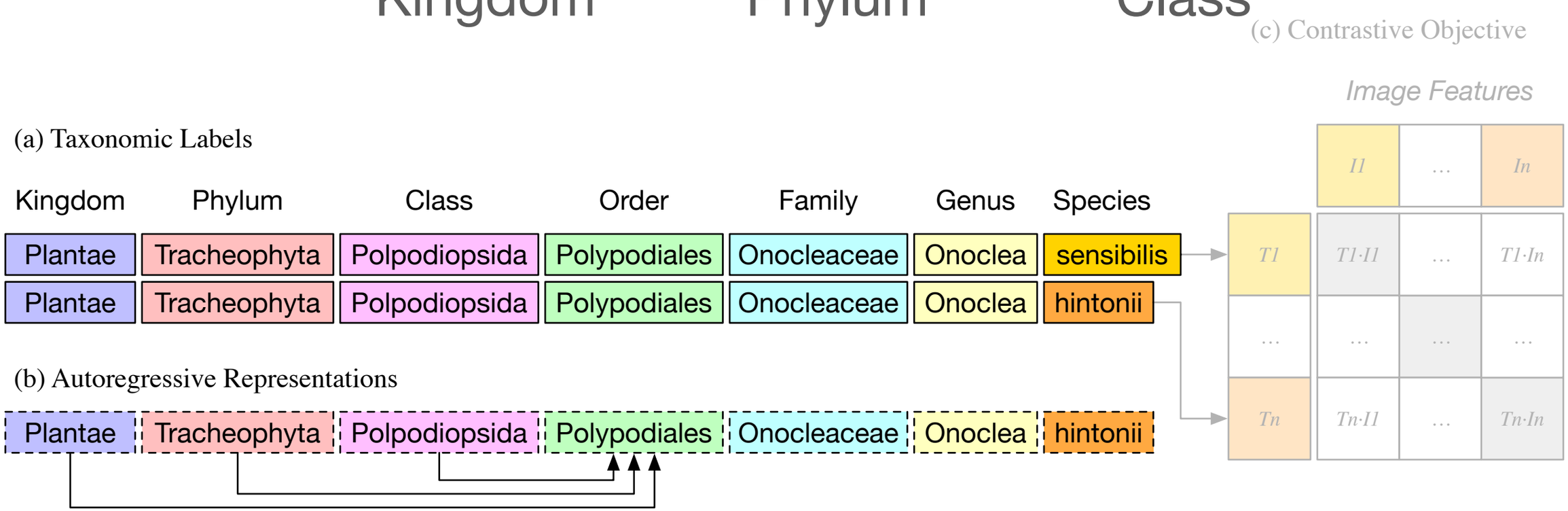
=

P(Polypodiales | Plantae Tracheophyta Popodiopsida Onocleaceae)

Order

“Polypodiales” only conditions on higher taxonomic levels.

Kingdom Phylum Class



P(Polypodiales | Plantae Tracheophyta Popodiopsida)

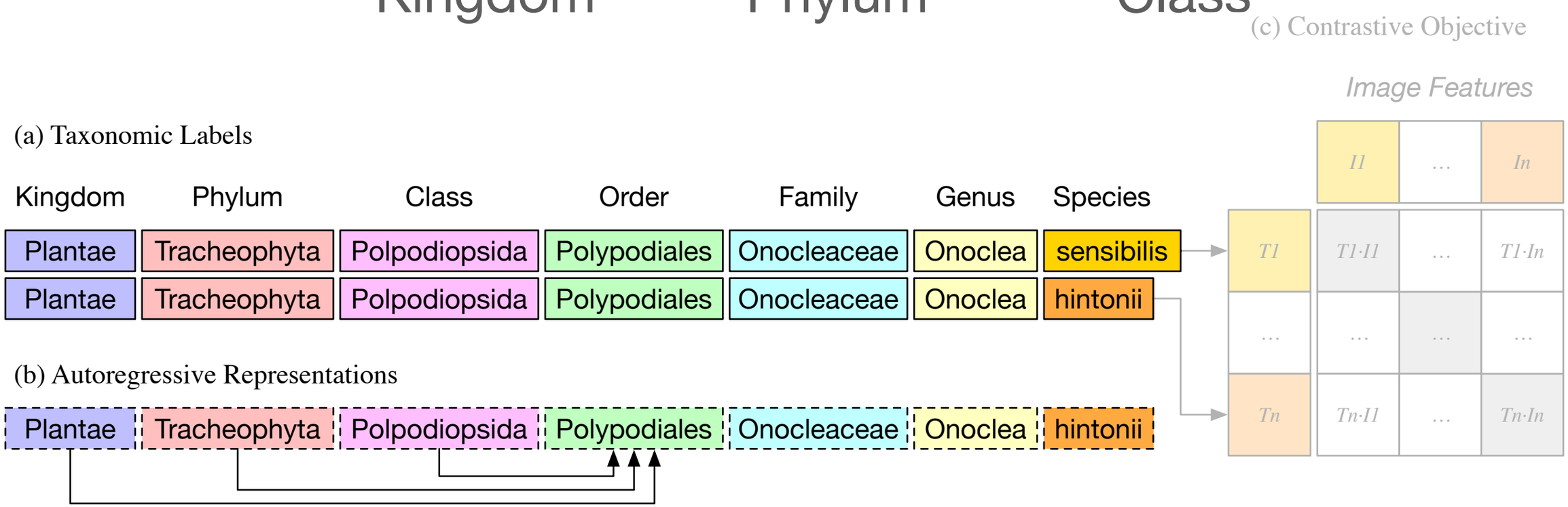
=

P(Polypodiales | Plantae Tracheophyta Popodiopsida Onocleaceae Onoclea)

Order

“Polypodiales” only conditions on higher taxonomic levels.

Kingdom Phylum Class



P(Polypodiales | Plantae Tracheophyta Popodiopsida)

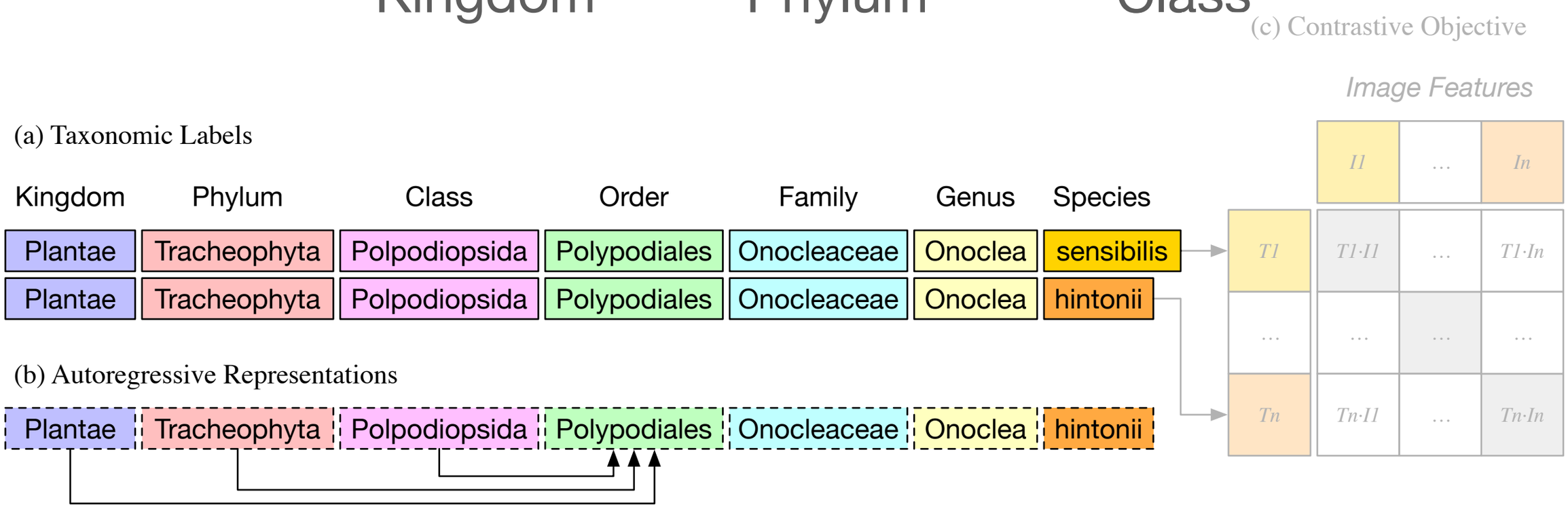
=

P(Polypodiales | Plantae Tracheophyta Popodiopsida Onocleaceae Onoclea hintonii)

Order

“Polypodiales” only conditions on higher taxonomic levels.

Kingdom Phylum Class



P(Polypodiales | Plantae Tracheophyta Popodiopsida Onocleaceae Onoclea sensibilis)

=

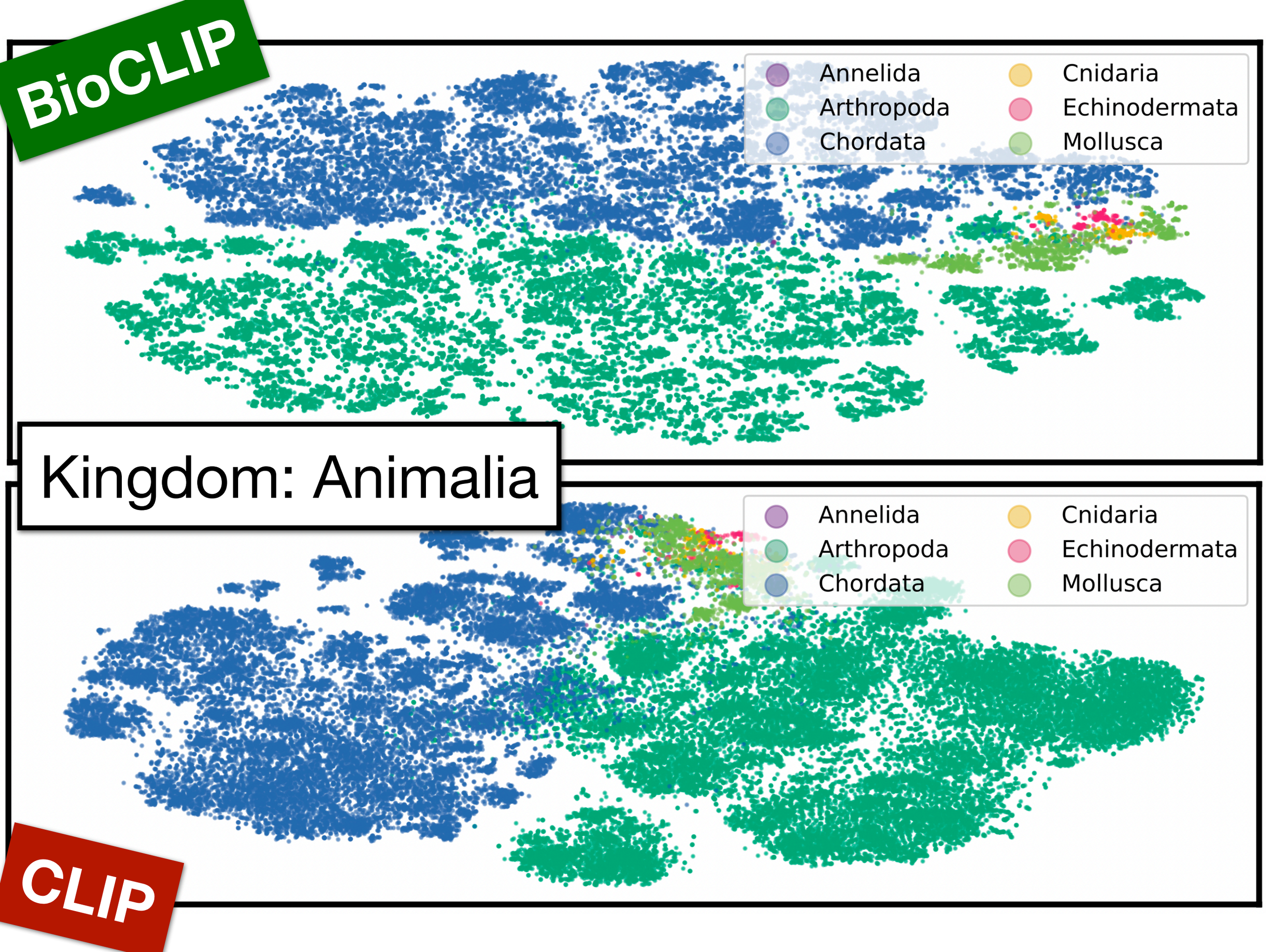
P(Polypodiales | Plantae Tracheophyta Popodiopsida Onocleaceae Onoclea hintonii)

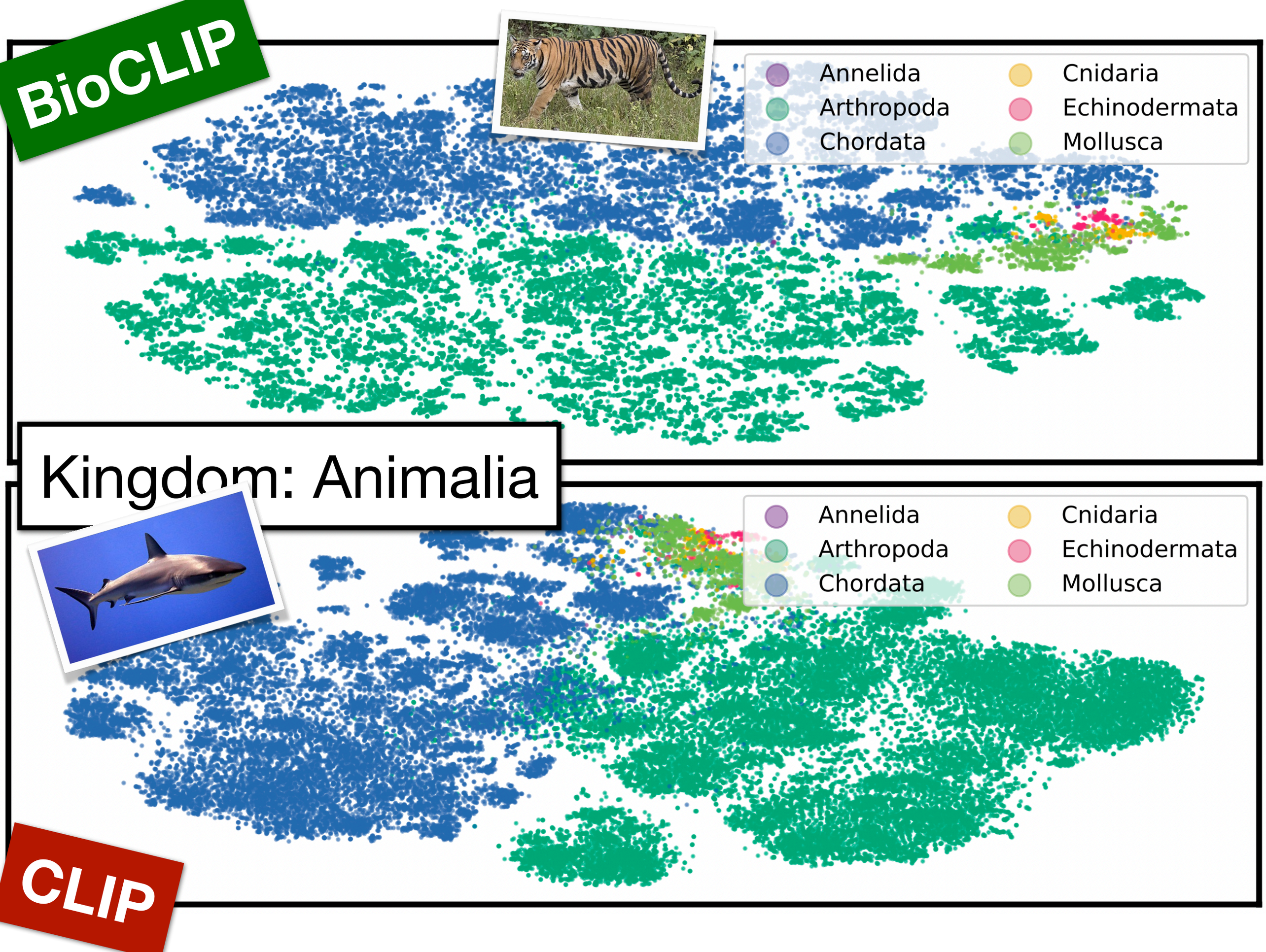
1. Biology is a fascinating computer vision problem.

2. Data is everything.

3. How does BioCLIP learn?

Pt. II


BioCLIP
Annelida
Arthropoda
Chordata
Cnidaria
Echinodermata
Mollusca
Kingdom: Animalia
Annelida
Arthropoda
Chordata
Cnidaria
Echinodermata
Mollusca
CLIP


BioCLIP
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Arthropoda
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Echinodermata
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Kingdom: Animalia
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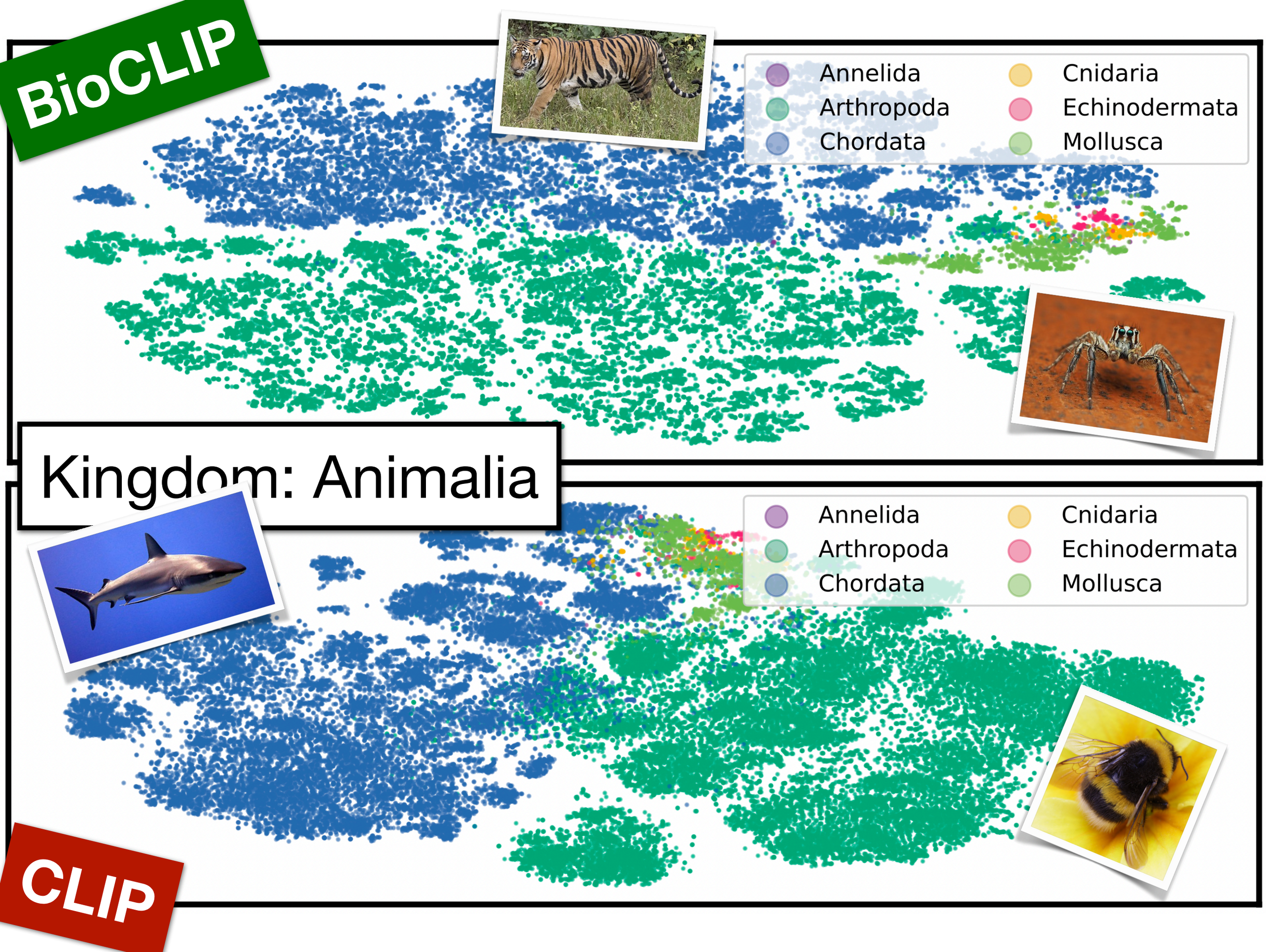
CLIP


BioCLIP
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Kingdom: Animalia
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Chordata
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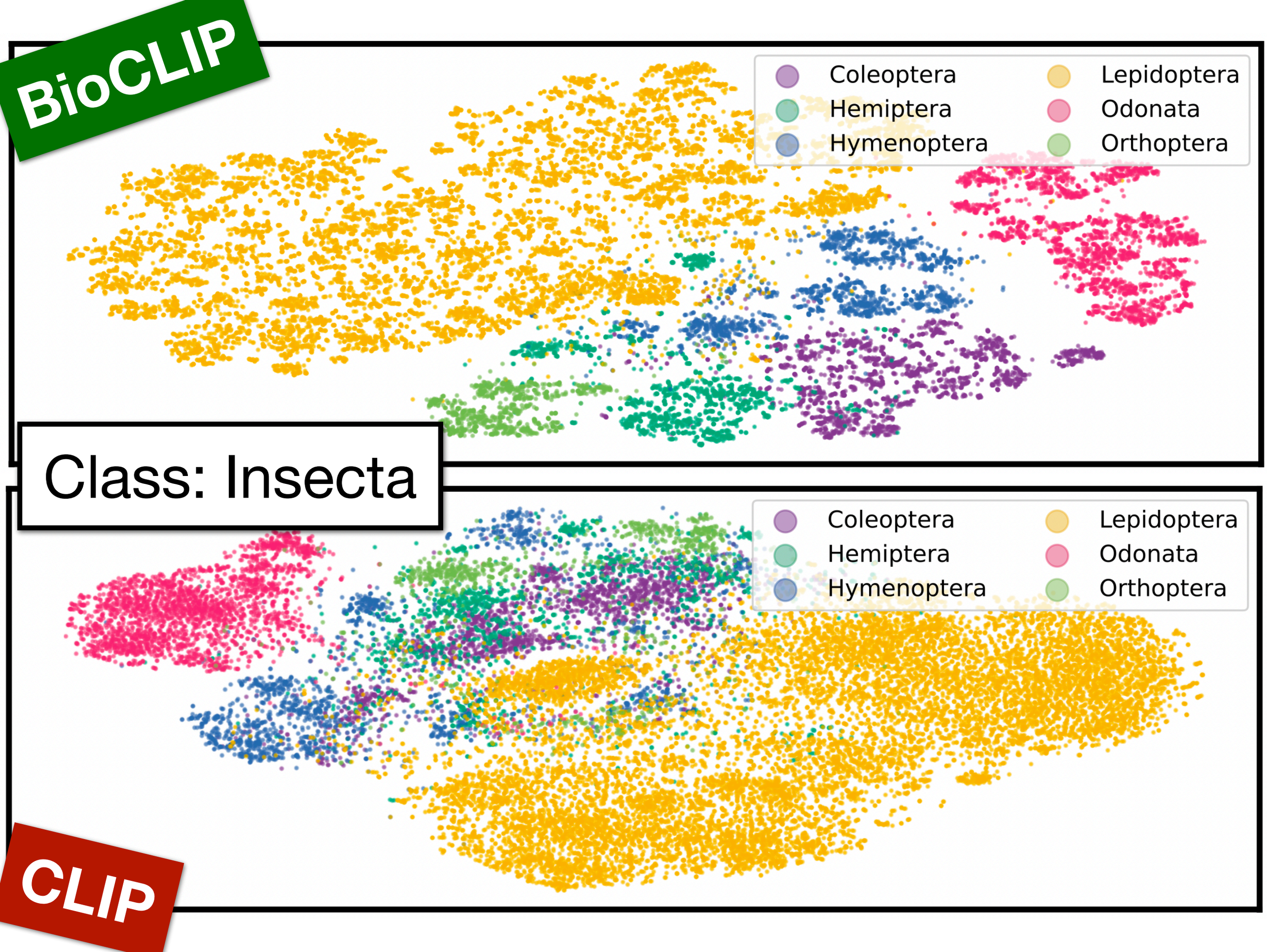
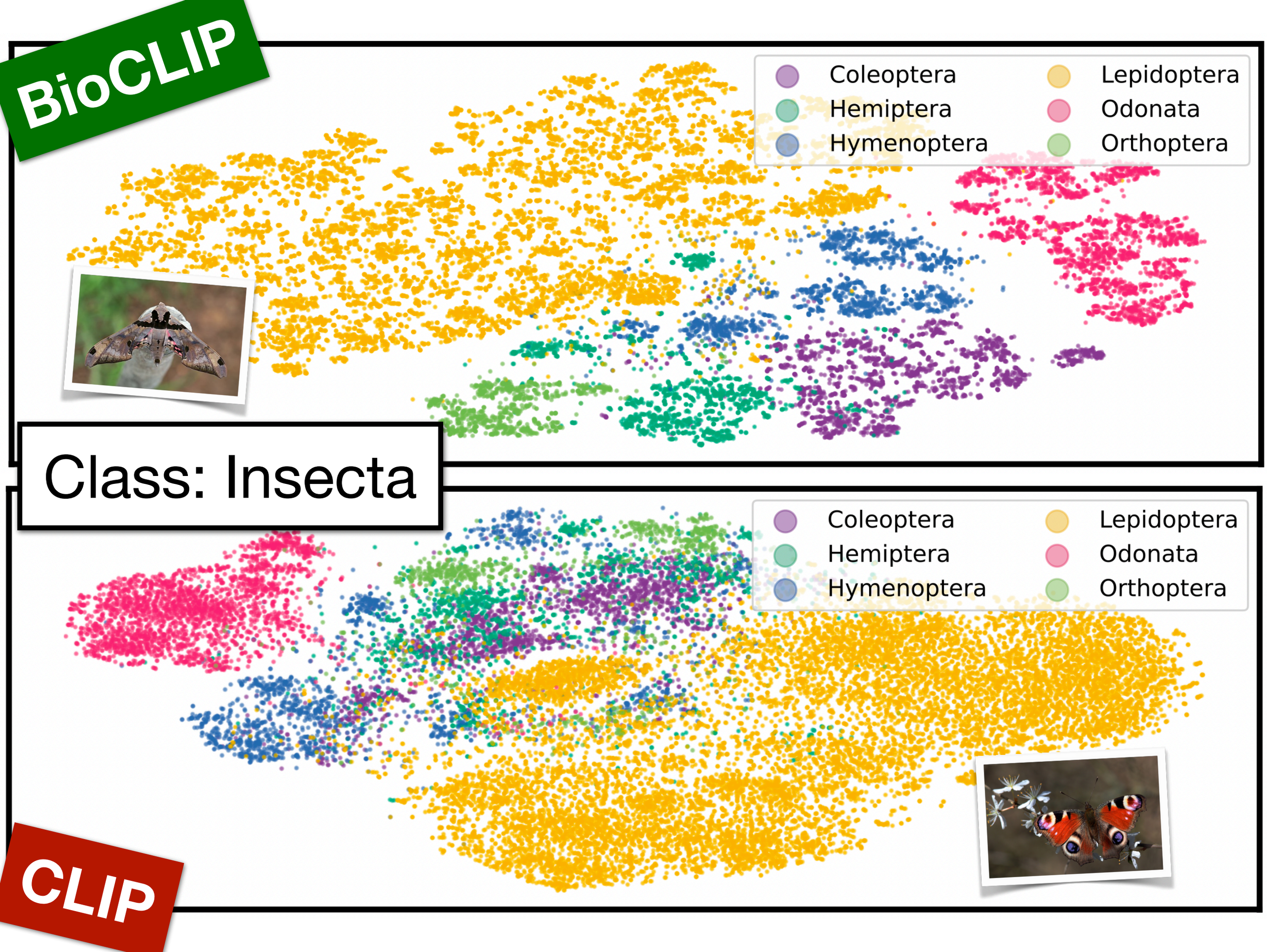
CLIP


BioCLIP
Coleoptera
Hemiptera
Hymenoptera
Lepidoptera
Odonata
Orthoptera
Class: Insecta
Coleoptera
Hemiptera
Hymenoptera
Lepidoptera
Odonata
Orthoptera
CLIP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Odonata
Orthoptera
Class: Insecta
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Hymenoptera
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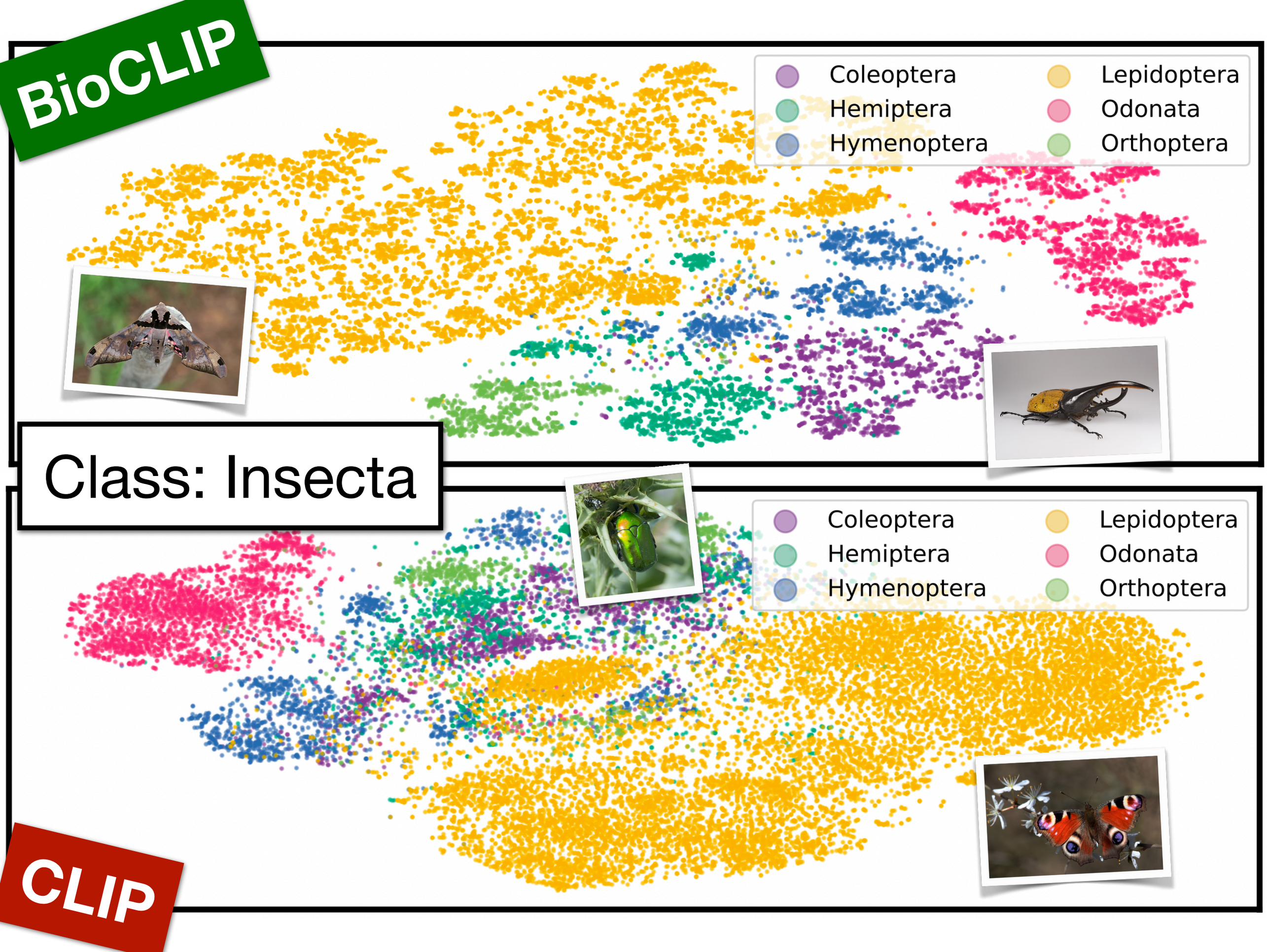
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Hymenoptera
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Odonata
Orthoptera
Class: Insecta
Coleoptera
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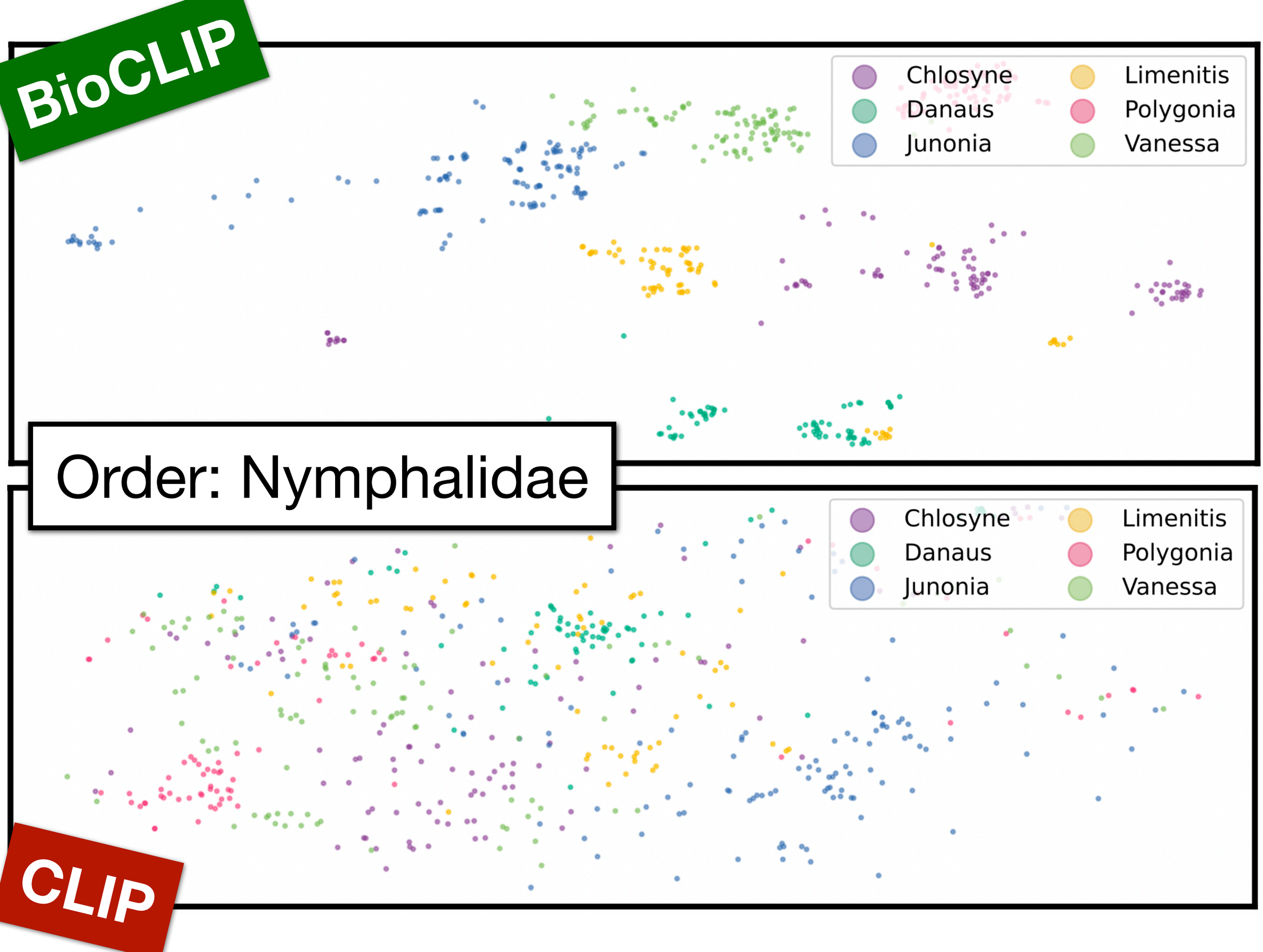
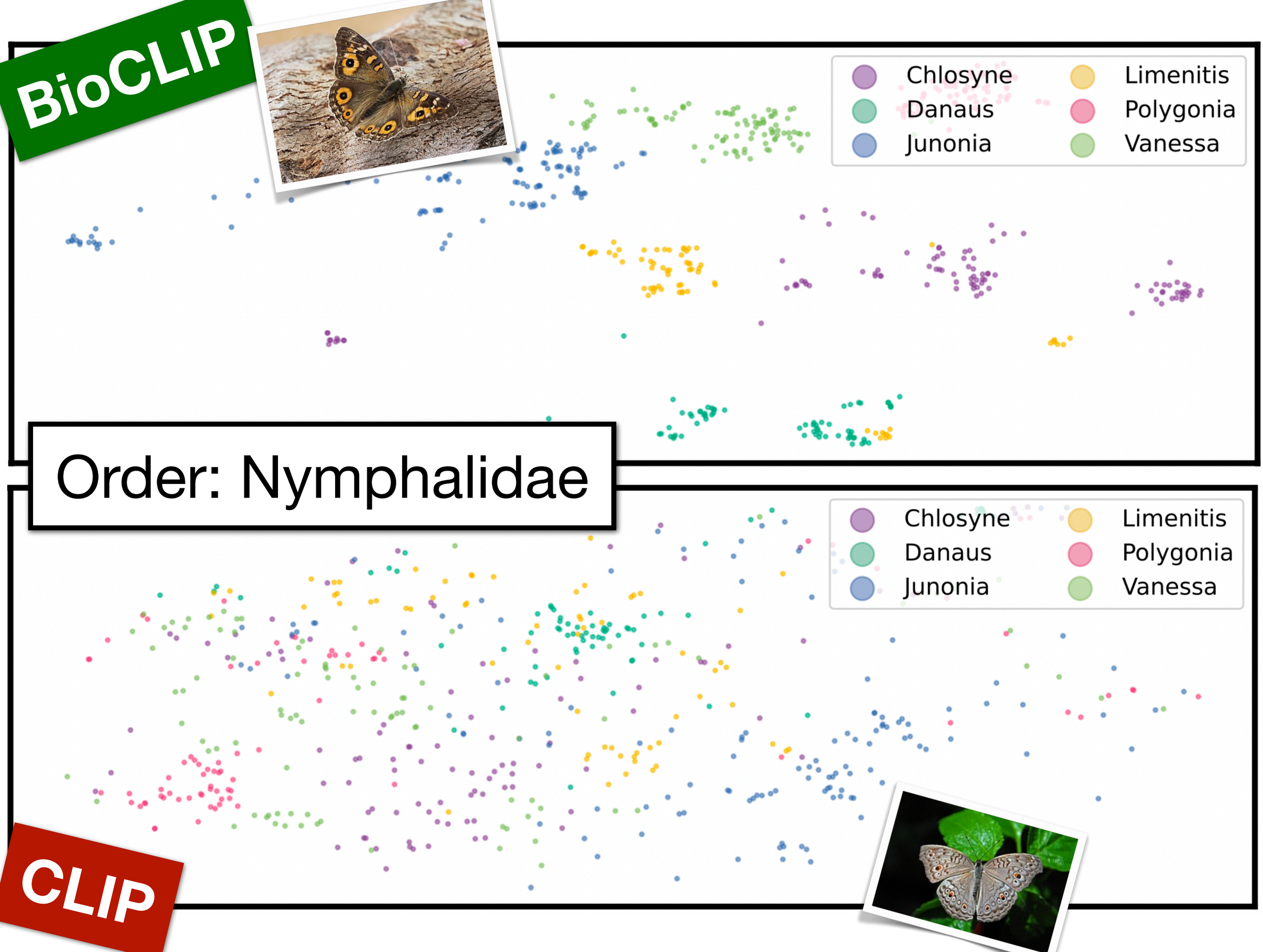
CLIP


BioCLIP
Chlosyne
Danaus
Junonia
Limenitis
Polygonia
Vanessa
Order: Nymphalidae
Chlosyne
Danaus
Junonia
Limenitis
Polygonia
Vanessa
CLIP


BioCLIP
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Vanessa
Order: Nymphalidae
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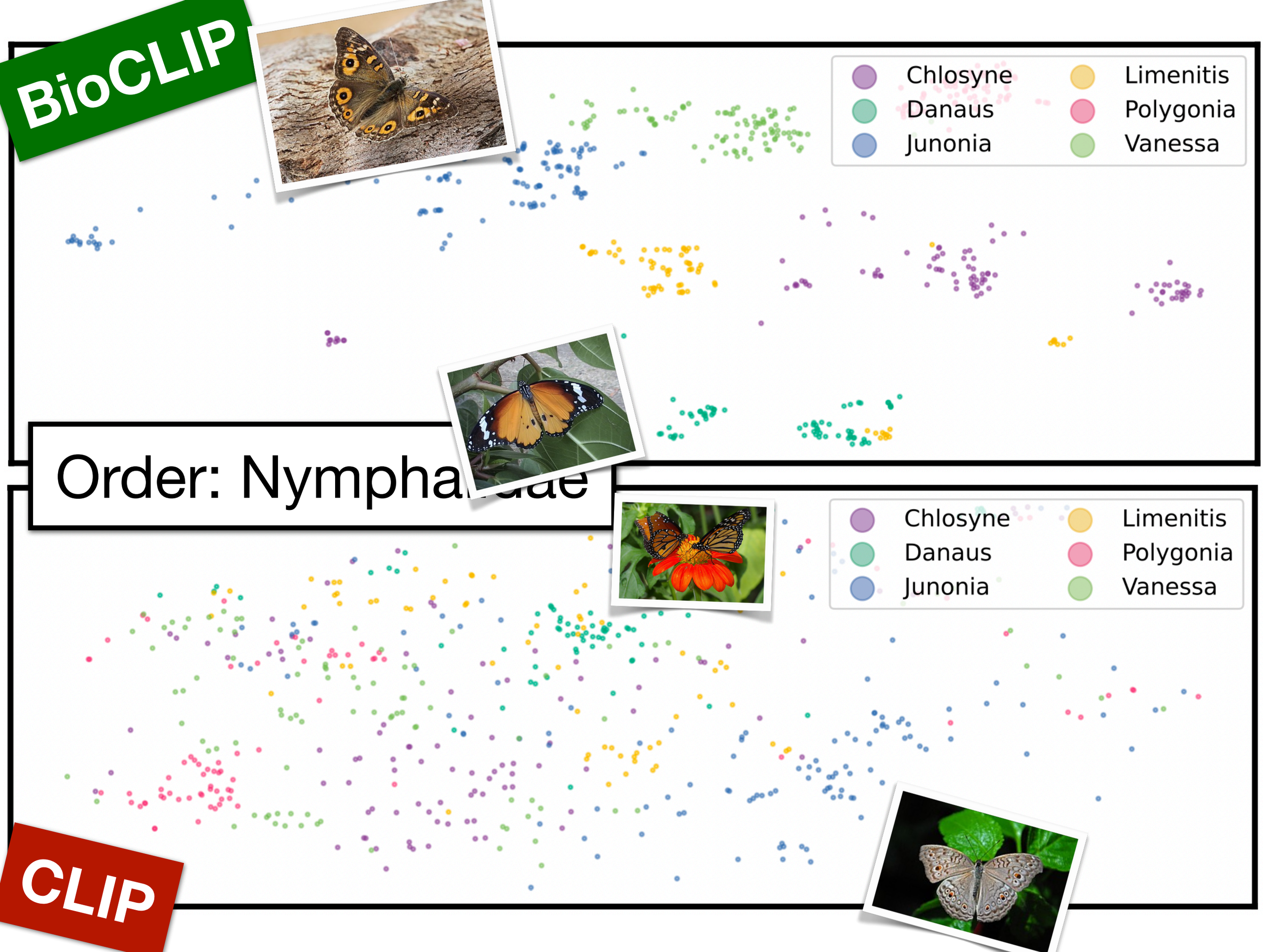
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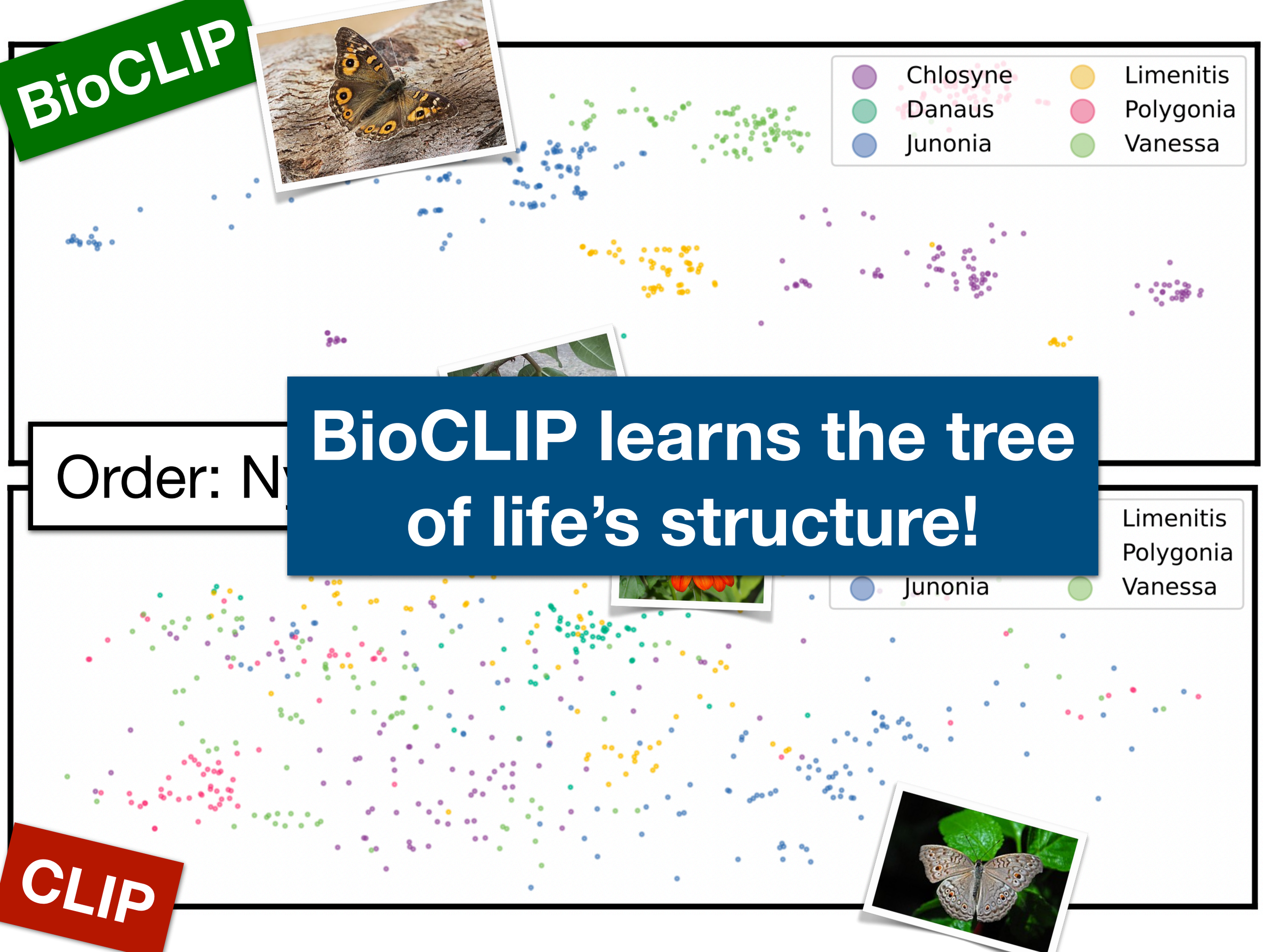

BioCLIP learns the tree of life's structure!

1. Biology is a fascinating computer vision problem.

2. Data is everything.

3. How does BioCLIP learn?

Call to Action

1. Go use BioCLIP.
2. Go train on TreeOfLife-10M.
3. Go solve computer vision for biology.

Call to Action

1. Go use BioCLIP.
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3. **Go solve computer vision for biology.**

BioCLIP

https://imageomics.github.io/bioclip/

Poster 298 at Arch 4E

🤗 Data 🤗 Models

Code ~~Paper~~

Best Student Paper 🏆

Sam Stevens*†, Jiaman Wu*, Matthew J Thompson, Elizabeth G Campolongo, Chan Hee Song, David Edward Carlyn, Li Dong, Wasila M Dahdul, Charles Stewart, Tanya Berger-Wolf, Wei-Lun Chao, Yu Su†

**Co-first authors*

†stevens.994@osu.edu, su.809@osu.edu