BIOSCAN-5M
A Multimodal Dataset for Insect Biodiversity

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Introduction to BIOSCAN-5M Dataset

A New Frontier in Insect Biodiversity Exploration

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Taxonomy

Phylum	Arthropoda
Class	Insecta
Order	Hymenoptera
Family	Formicidae
Subfamily	Dolichoderinae
Genus	*Tapinoma*
Species	*Tapinoma sessile*
BIN	BOLD:AAA3908

DNA Barcode

Thymine	T
Cytosine	C
Guanine	G
Cytosine	C
Thymine	T
Adenine	A
.	
.	
.	

Geographic Data

Country	United States
Province/State	California
Latitude	40.10132
Longitude	-122.05354

Size Data

Meas.Value	64,331
Area Fraction	0.40
Scale Factor	2.08

Image Data

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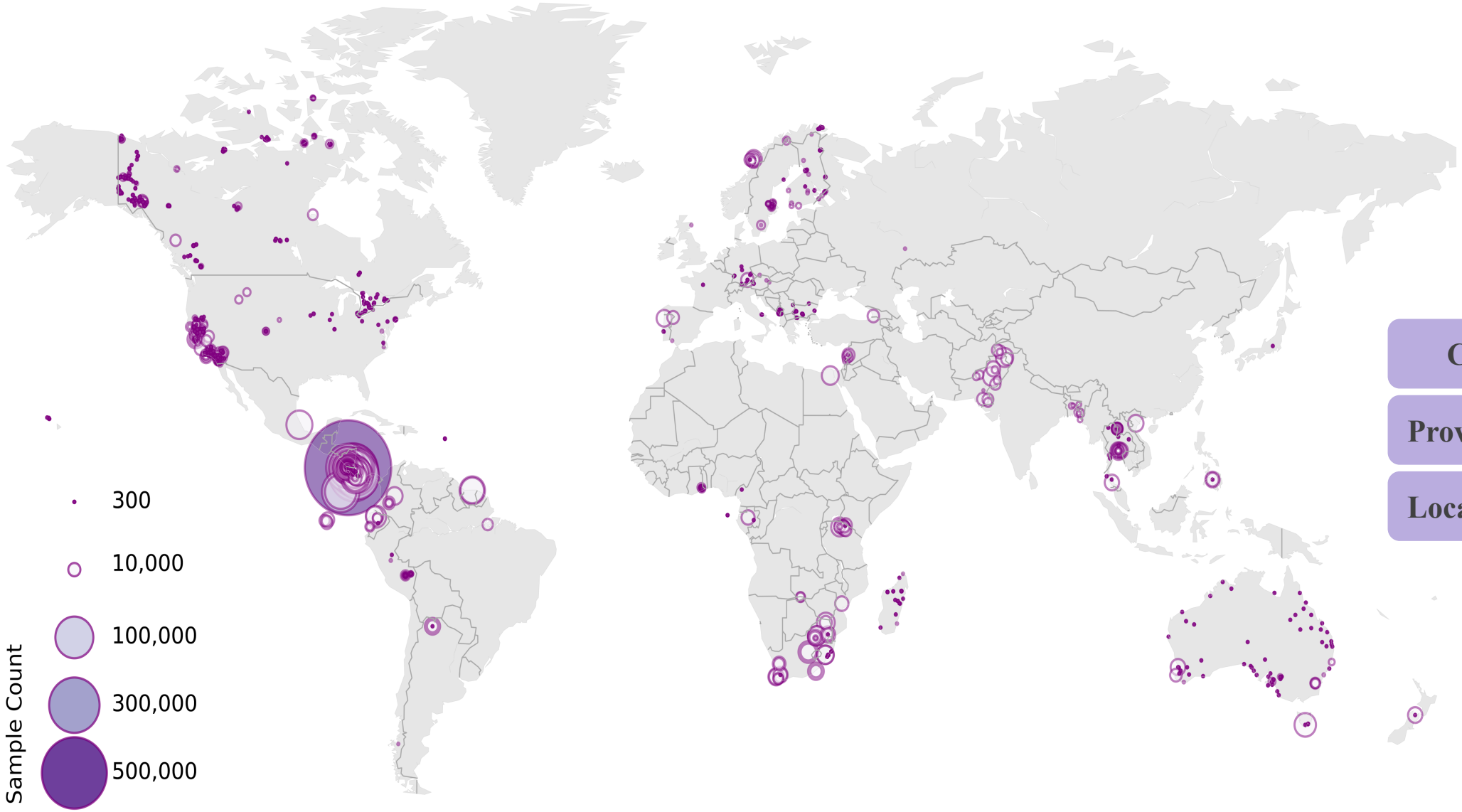

	Count
Country	47
Province/State	102
Location (Lat, Lon)	1,650

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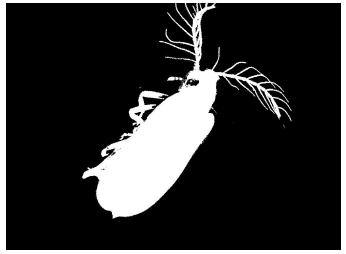
Meas.Value

$$f_p = \sum_{n=1}^{N} p_i$$

$$p_i = \begin{cases} 1 & \text{If pixel } i \text{ occupied} \\ 0 & \text{Otherwise} \end{cases}$$

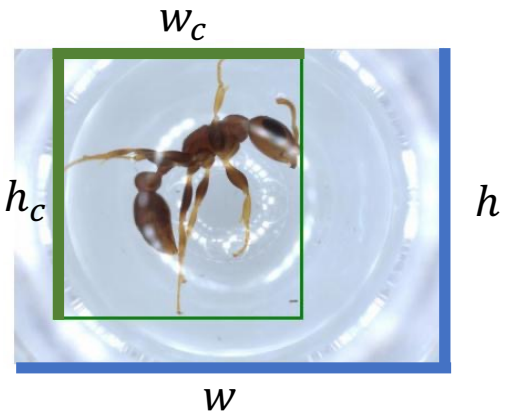



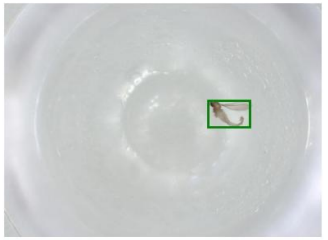
Area Fraction

$$f_a = \frac{w_c h_c}{w\ h}$$

Scale Factor

$$f_s = \frac{\min(w_c,\ h_c)}{256}$$

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Statistical Insights into BIOSCAN-5M

Uncovering Patterns in Insect Biodiversity

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	Labelled Records		Categories				Unique DNA	
			Count	Imbalance Ratio	Most Populated	Least Populated	Count	Avg SDI
Phylum	5,150 k	100%	1	1	5,150 k	5,150 k	2,486 k	19.78
Class	5,146 k	99.9%	10	719 k	5,038 k	7	2,482 k	8.56
Order	5,134 k	99.7%	55	3,675 k	3,675 k	1	2,474 k	7.05
Family	4,932 k	95.8%	934	938 k	938 k	1	2,321 k	5.42
Subfamily	1,472 k	28.6%	1,542	323 k	323 k	1	657 k	4.28
Genus	1,226 k	23.8%	7,605	200 k	200 k	1	531 k	2.63
Species	473 k	9.2%	22,622	7,694	7,694	1	202 k	1.46

Practical Insights into BIOSCAN-5M

Revealing Biodiversity Patterns for Real-World Impact

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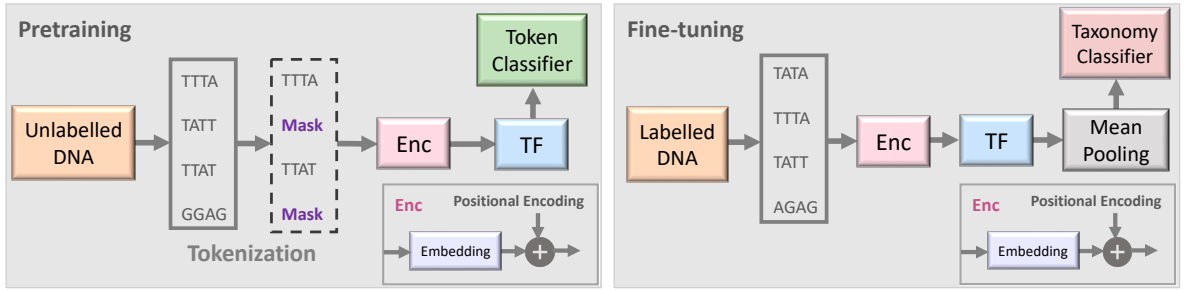
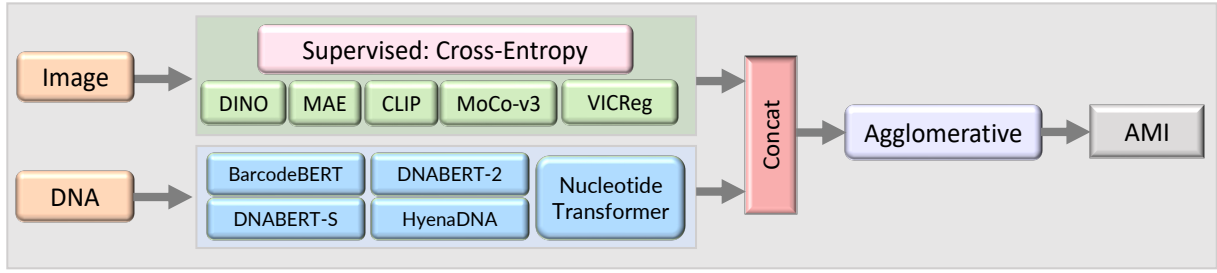
Data partitioning supporting both closed- and open world settings

Benchmark experiments

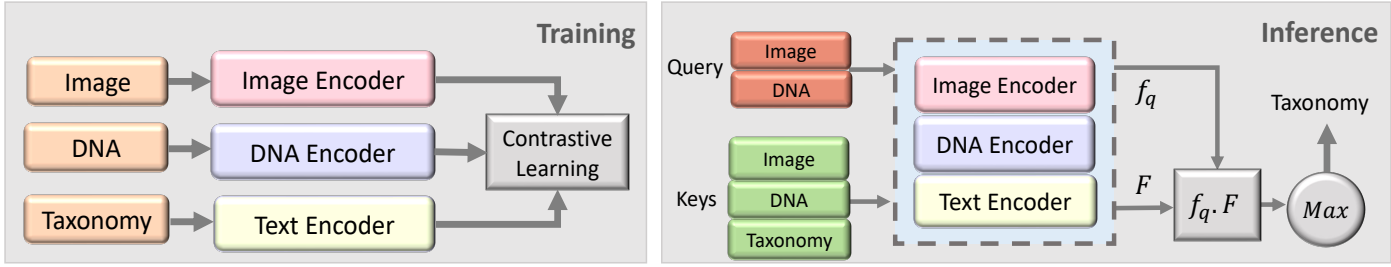
- DNA based taxonomic classification



- Zero-shot transfer learning



- Multimodal retrieval learning



From Data to Discovery

Data Partitioning for Bridging Known and Novel Species

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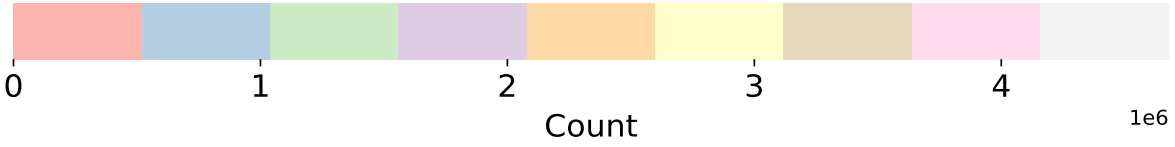
Species	Split sets	Applications	Samples	Barcodes	Species
Unknown	pretrain	Self- and semi-supervised learning	4678 k	2284 k	0
Seen	train	Supervised learning, retrieval keys	289 k	118 k	12 k
	val	Model development; retrieval queries	15 k	7 k	3 k
	test	Final evaluation; retrieval queries	39 k	18 k	3 k
Unseen	key_unseen	Retrieval keys	36 k	12 k	914
	val_unseen	Model development; retrieval queries	9 k	2 k	903
	test_unseen	Final evaluation; retrieval queries	8 k	3 k	880
Heldout	other_heldout	Novelty detector training	77 k	41 k	10 k



Real-World Applications of BIOSCAN-5M

DNA Based Taxonomic Classification

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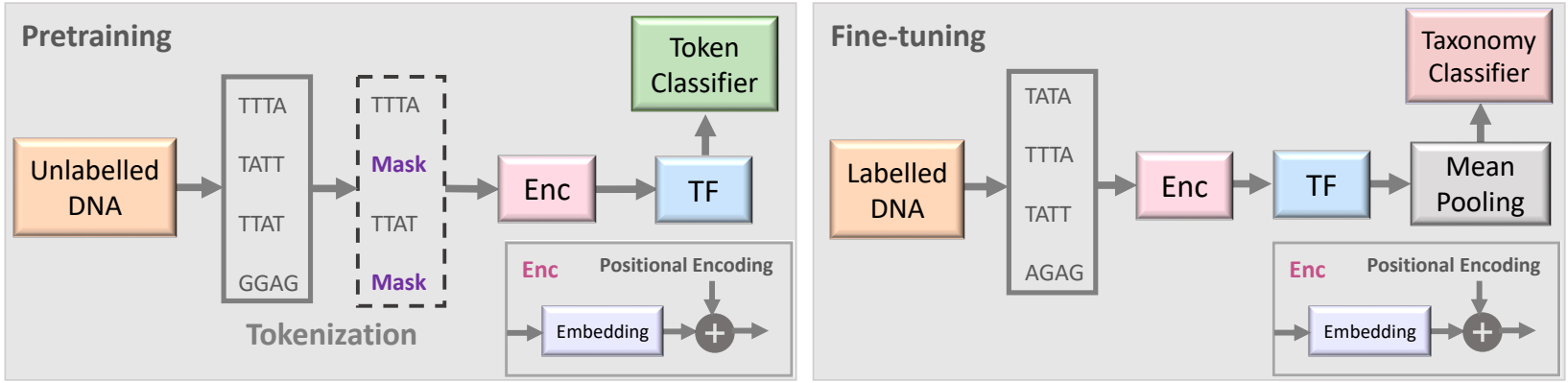
Best Model

Second Best Model



				Seen: Species		Unseen: Genus
Model	**Architecture**	**SSL-Pretraining**	**Token seen**	**Fine-tuned**	**Linear probe**	**1NN-Probe**
CNN Baseline	CNN	-	-	97.70	-	29.88
NT	Transformer	Multi-Species	300 B	98.99	52.41	21.67
DANBERT-2	Transformer	Multi-Species	512 B	99.23	67.81	17.99
DANBERT-S	Transformer	Multi-Species	~ 1,000 B	98.99	95.50	17.70
HyenaDNA	SSM	Human DNA	5 B	98.71	54.82	19.26
BarcodeBERT	Transformer	DNA barcodes	5 B	98.52	91.93	23.15
Ours	Transformer	DNA barcodes	7 B	99.28	94.47	47.03

Real-World Applications of BIOSCAN-5M

Zero-shot Transfer Learning

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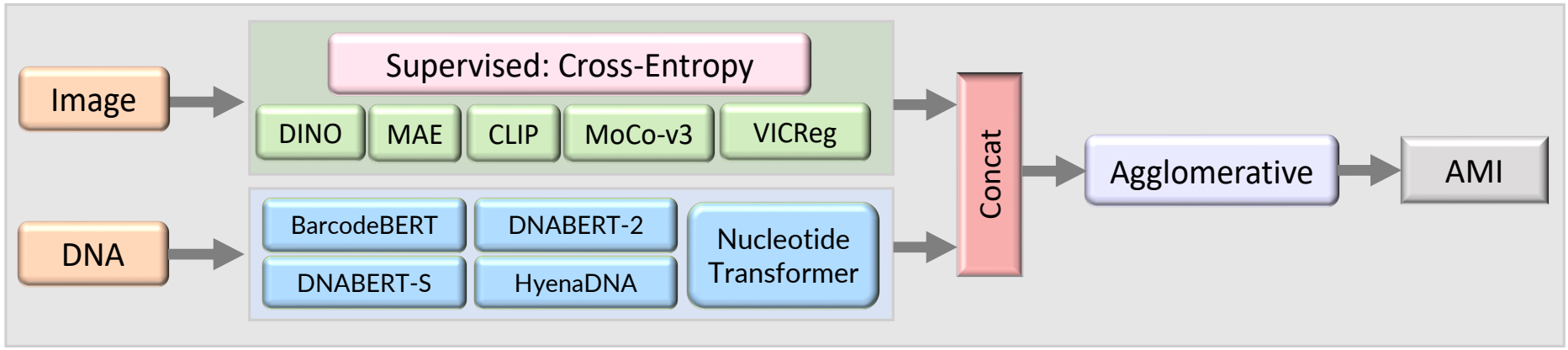

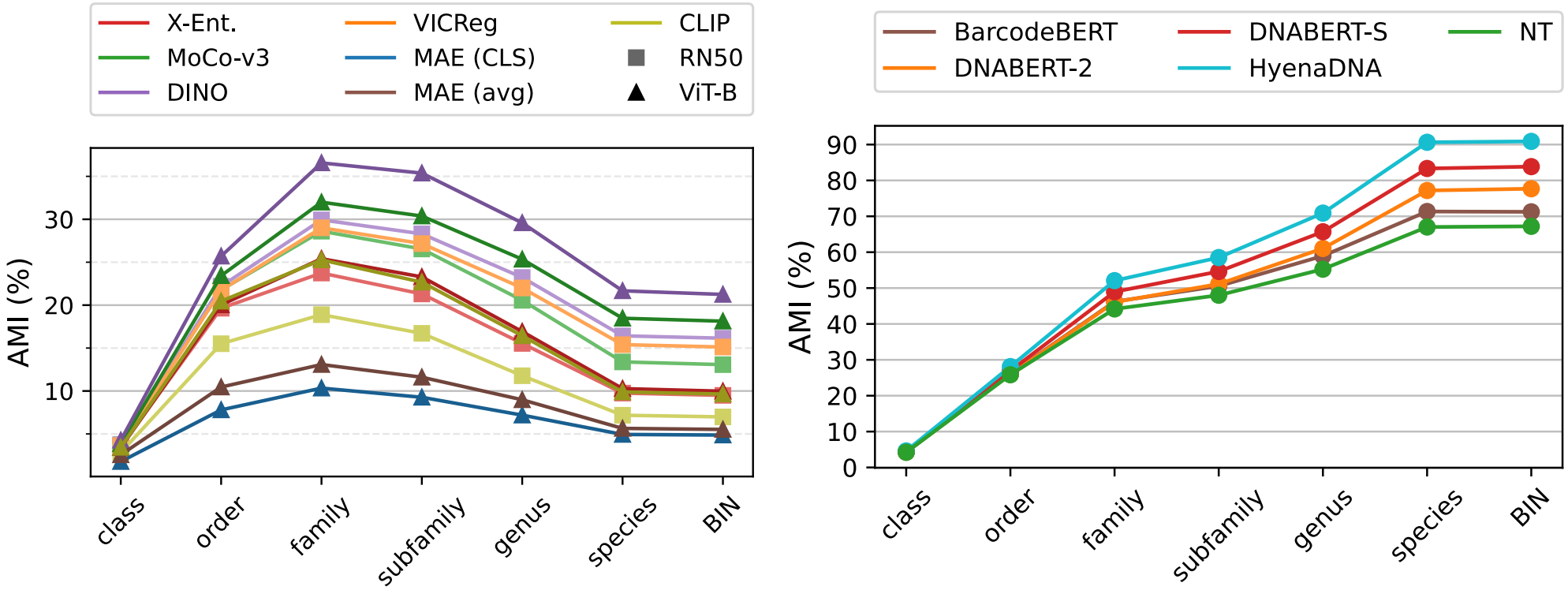

Real-World Applications of BIOSCAN-5M

Multimodal Retrieval Learning

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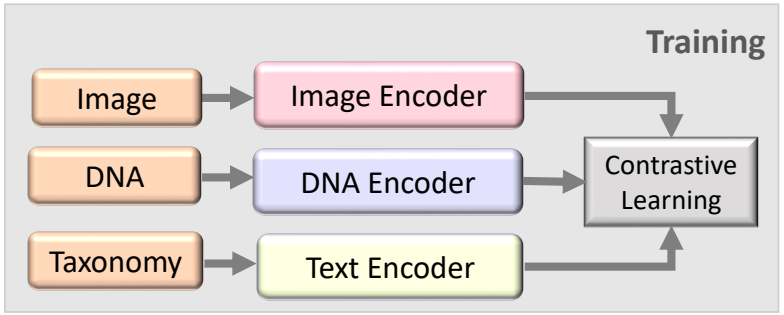
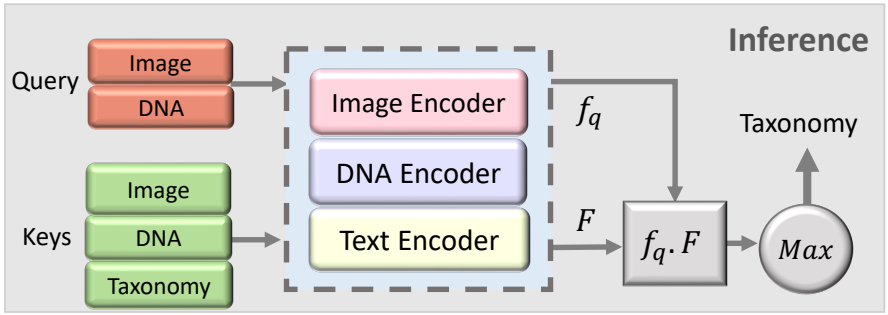
Taxonomy Prediction: **Species**

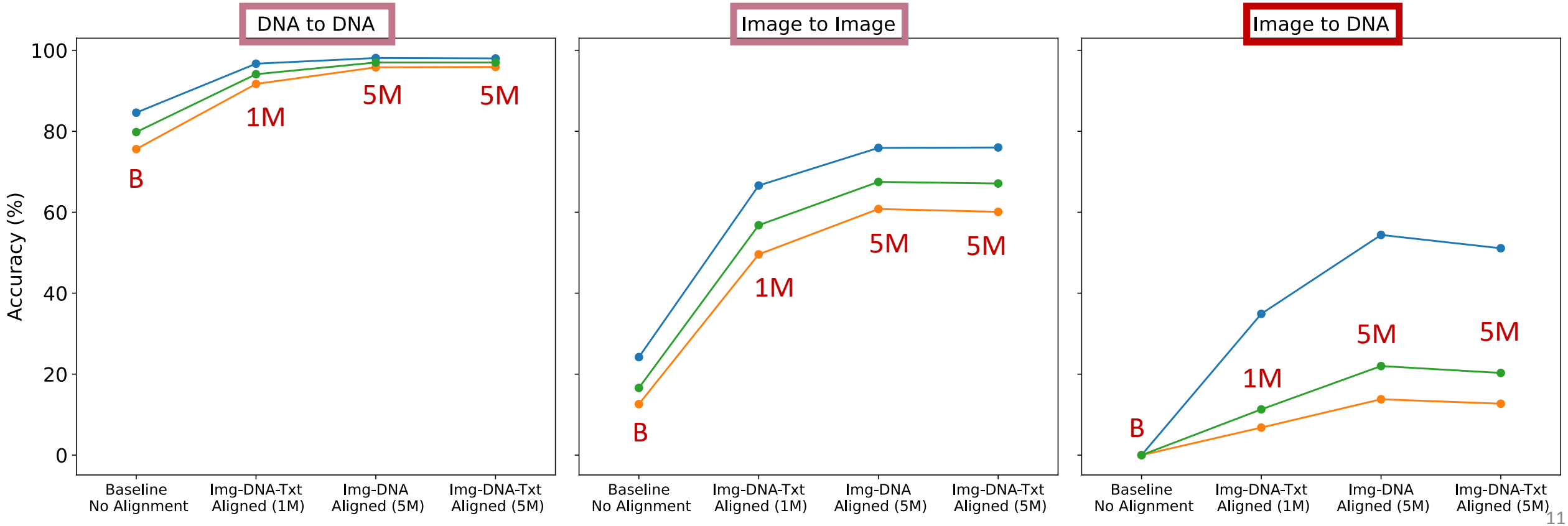
Seen

Unseen

Harmonic Mean of seen and unseen







Real-World Applications of BIOSCAN-5M

Multimodal Retrieval Learning

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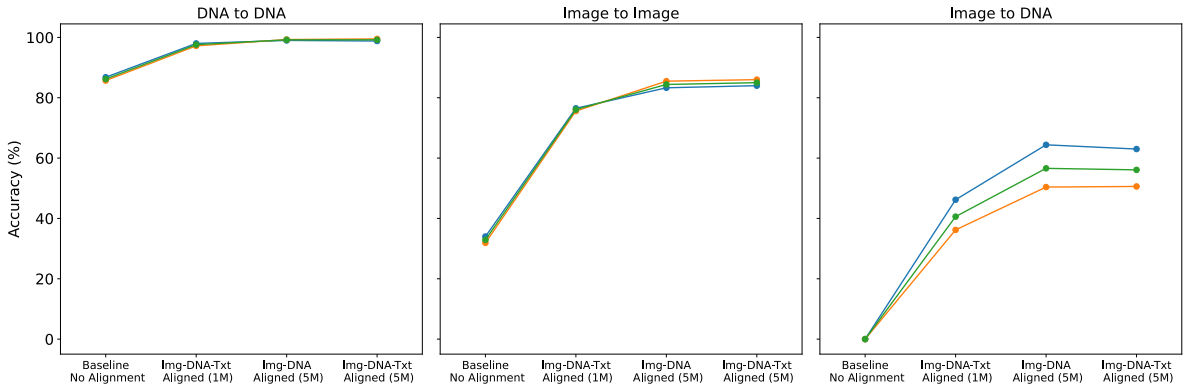
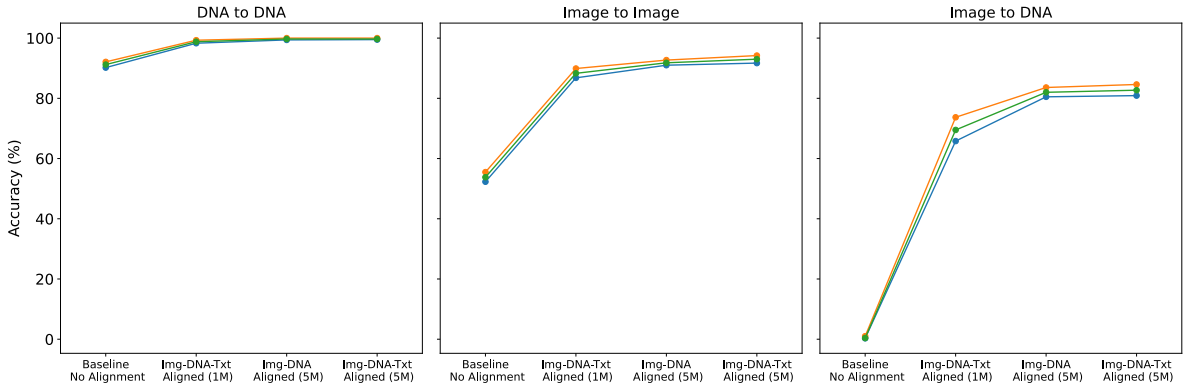
Seen
Unseen
Harmonic Mean of seen and unseen

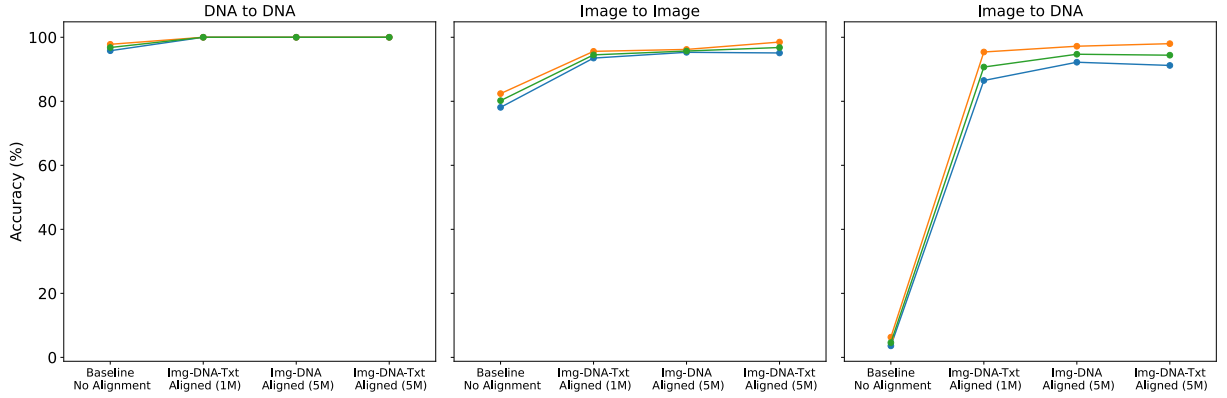
Genus



Family



Order



Key Takeaways from BIOSCAN-5M Research

Conclusion & Resources for Continued Exploration

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BIOSCAN-5M offers

- A comprehensive resource with **over 5 million** arthropod specimens.
- **Multimodal** data including images, DNA barcodes, and taxonomic text annotations.
- **Data partitions** for both **closed-** and **open-world** machine learning settings.
- **Benchmark** experiments for fine-grained taxonomic classification and zero-shot clustering.

Future plans

- Advancing **biodiversity monitoring** by developing models for **species categorization** and **novel species discovery**.
- Fostering **collaborative** projects and initiatives inspired by BIOSCAN-5M to map and preserve **global biodiversity through machine learning.**

Preprint	https://arxiv.org/abs/2406.12723
Github	https://github.com/bioscan-ml/BIOSCAN-5M
GoogleDrive	https://drive.google.com/drive/u/0/folders/1Jc57eKkeiYrnUBc9WlIp-ZS_L1bVlT-0
Zenodo	https://zenodo.org/records/11973457
Kaggle	https://www.kaggle.com/datasets/zahragharaee/bioscan-5m
HuggingFace	https://huggingface.co/datasets/Gharaee/BIOSCAN-5M
Contact	zahra.gharaee@gmail.com

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https://biodiversitygenomics.net/projects/5m-insects/

Thank you for your engagement.

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