

Using topology to analyze the shape of barley

Euler meets plant biology

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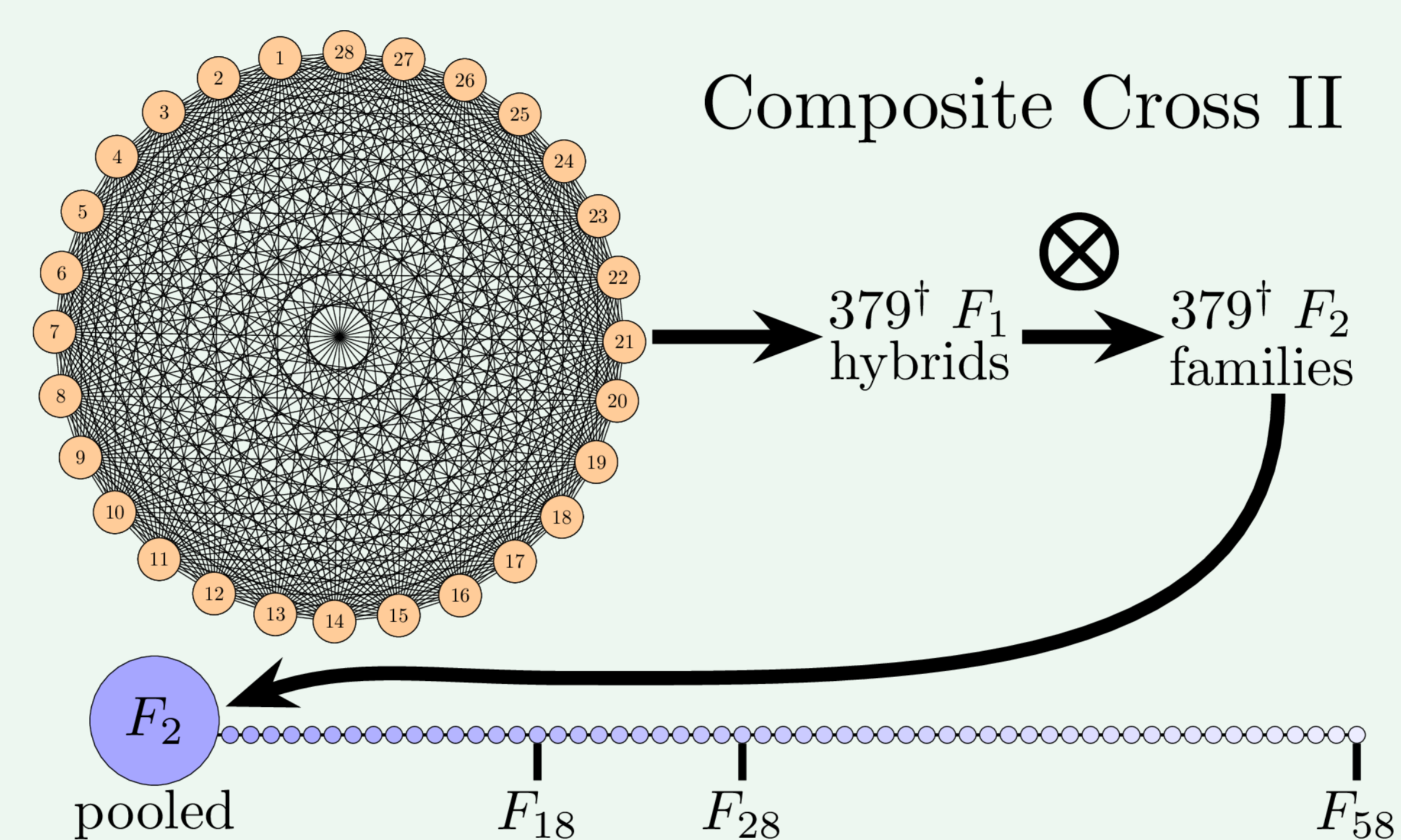
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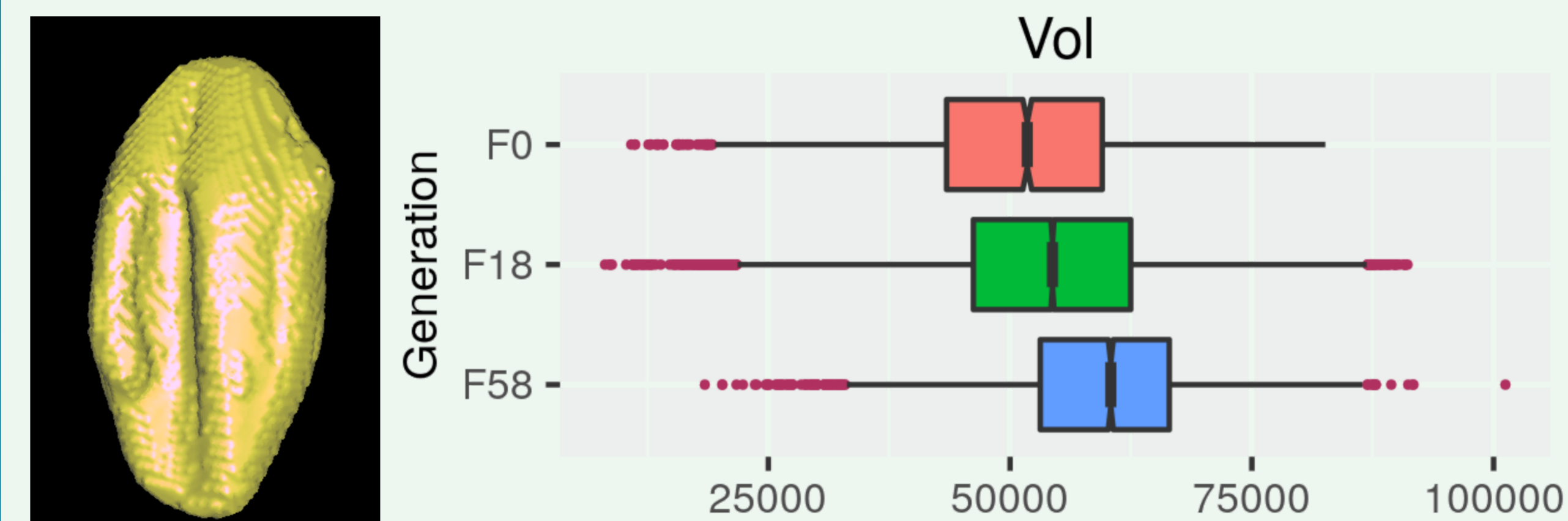
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Barley Experimental Design



- 28 founders (land races). 58 generations.

Image processing to measure seeds



- 3D X-ray CT scan data: 875 barley spikes.
- 38,000 seeds: generations F₀, F₁₈, and F₅₈.
- Distribution of length, height, width, volume, etc.

SVM Classification Results

Shape descriptors	# descr	F1 Score
Traditional	11	0.55 ± 0.019
Topological (ECT + UMAP)	12	0.74 ± 0.016
Combined (Trad + Topo)	23	0.86 ± 0.010

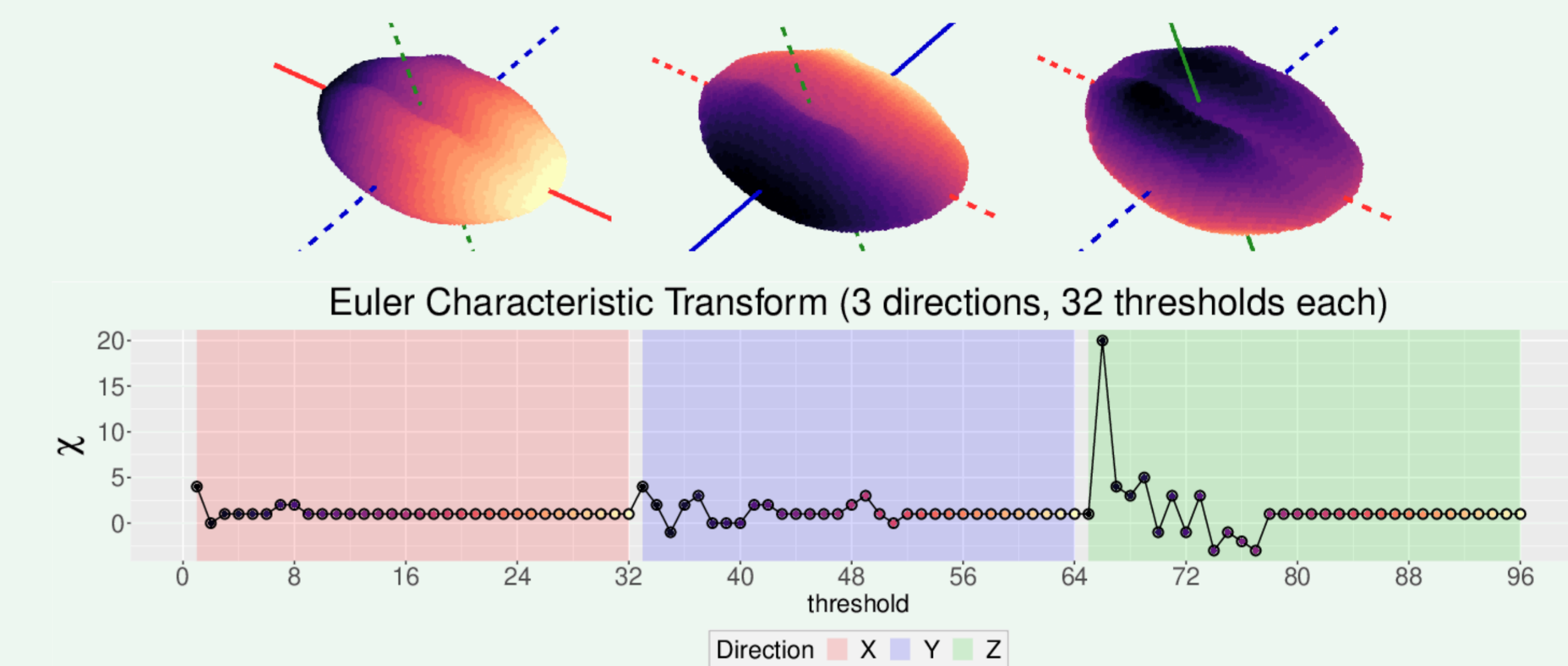
- SVM to classify 3,000 seeds from the 28 founders
- (75% training vs 25% testing) × 50 times
- **Up to 84% classification accuracy**

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Euler characteristic transform (ECT)

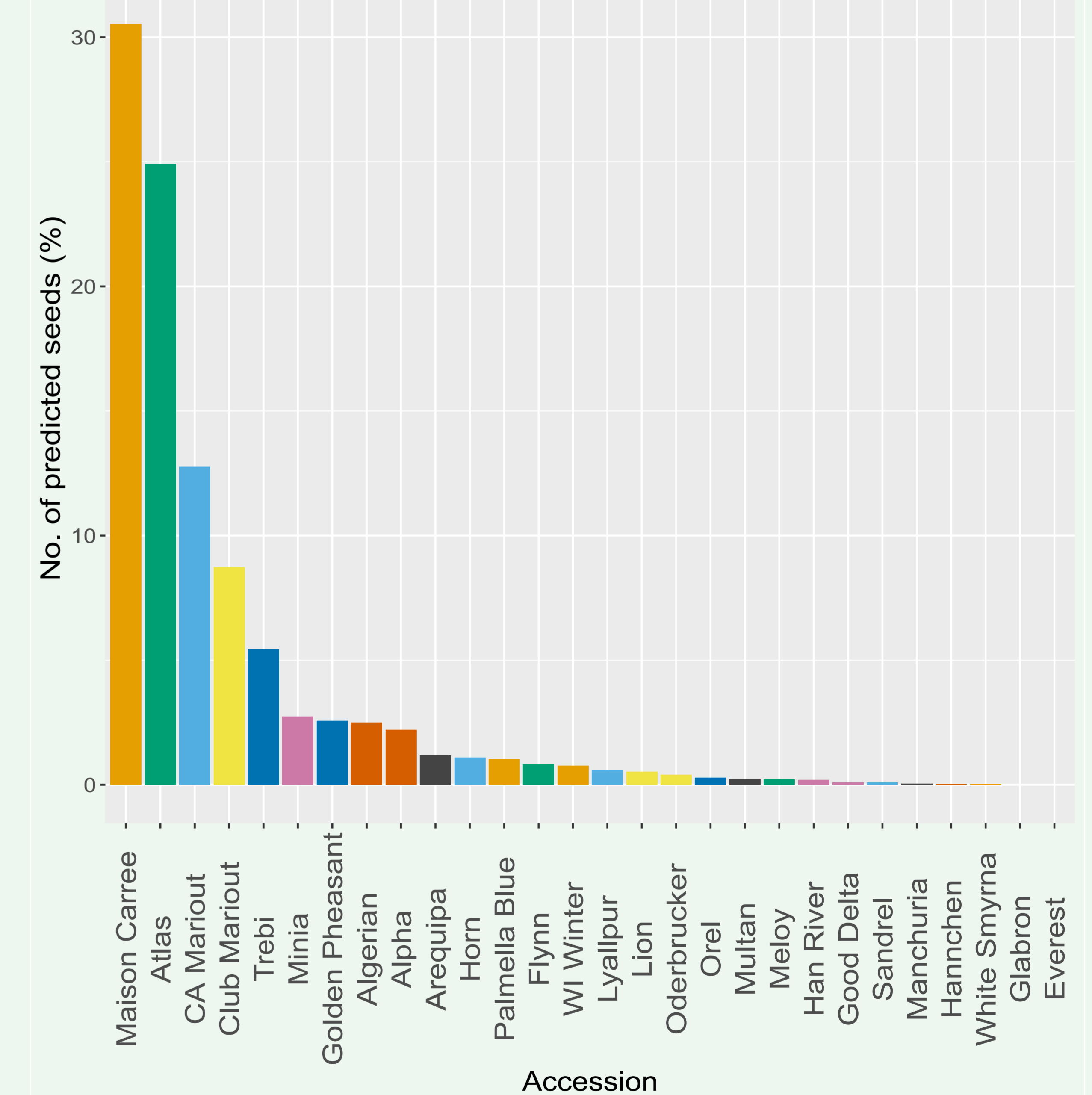
$$\chi = \#(\text{Vertices}) - \#(\text{Edges}) + \#(\text{Faces})$$

- ECT is the record of how the EC changes as we reconstruct a given object in all possible directions.
- The ECT summarizes all shape information [2].



Semi-supervised learning

Gen 58 distribution (UMAP Combined, topounscaled)



- Train with 100% of the founder seeds
- Classify 6000 unlabeled seeds from F₅₈
- Three morphologies are enriched through time.
- Similar conclusion with genomic analysis!

References

[1] EJA, M. Quigley, T. Ophelders, J. Landis, D. Koenig, E. Munch, D. Chitwood (2022) "Measuring hidden phenotype: quantifying the shape of barley seeds using the Euler characteristic transform," *in silico Plants*, 4(1) diab033

[2] K. Turner, S. Mukherjee, D. M. Boyer (2014) "Persistent homology transform for modeling shapes and surfaces," *Information and Inference*, 3(4) 310–344.

[10.1093/insilicoplants/diab033](https://doi.org/10.1093/insilicoplants/diab033)

