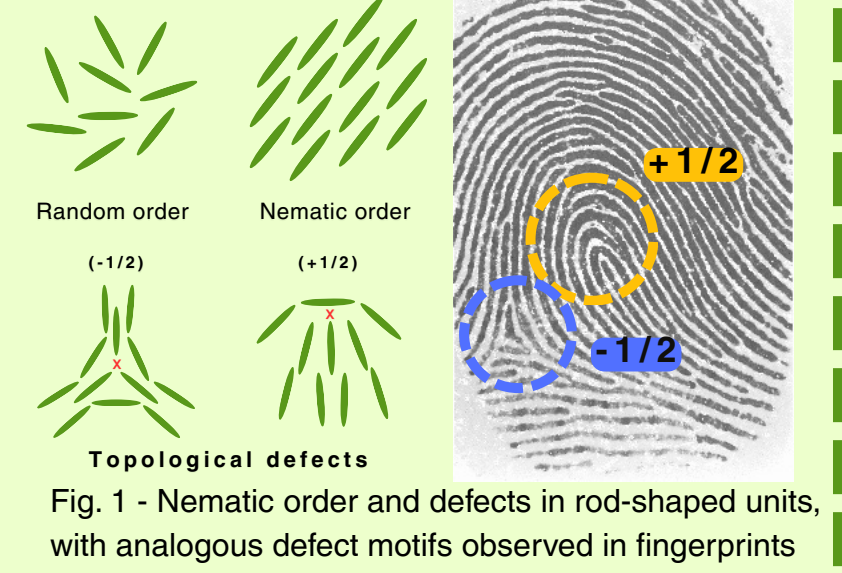


# Fingerprints as frozen nematic fields

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## NEMATICS & MORPHOGENESIS

- Nematic liquid crystals are a phase of matter with two key characteristics:
  - Long-range **orientational order** & topological **defects** [1]
- The nematic phase has been demonstrated as a **self-organisation force** across different biological systems, from **cell monolayers** to **actin networks** [2]
- Fingerprint ridges** embody the **director fields** of a nematic, with patterns appearing as characteristic **half-integer defects**



## FINGERPRINTS AS NEMATIC TOPOLOGIES

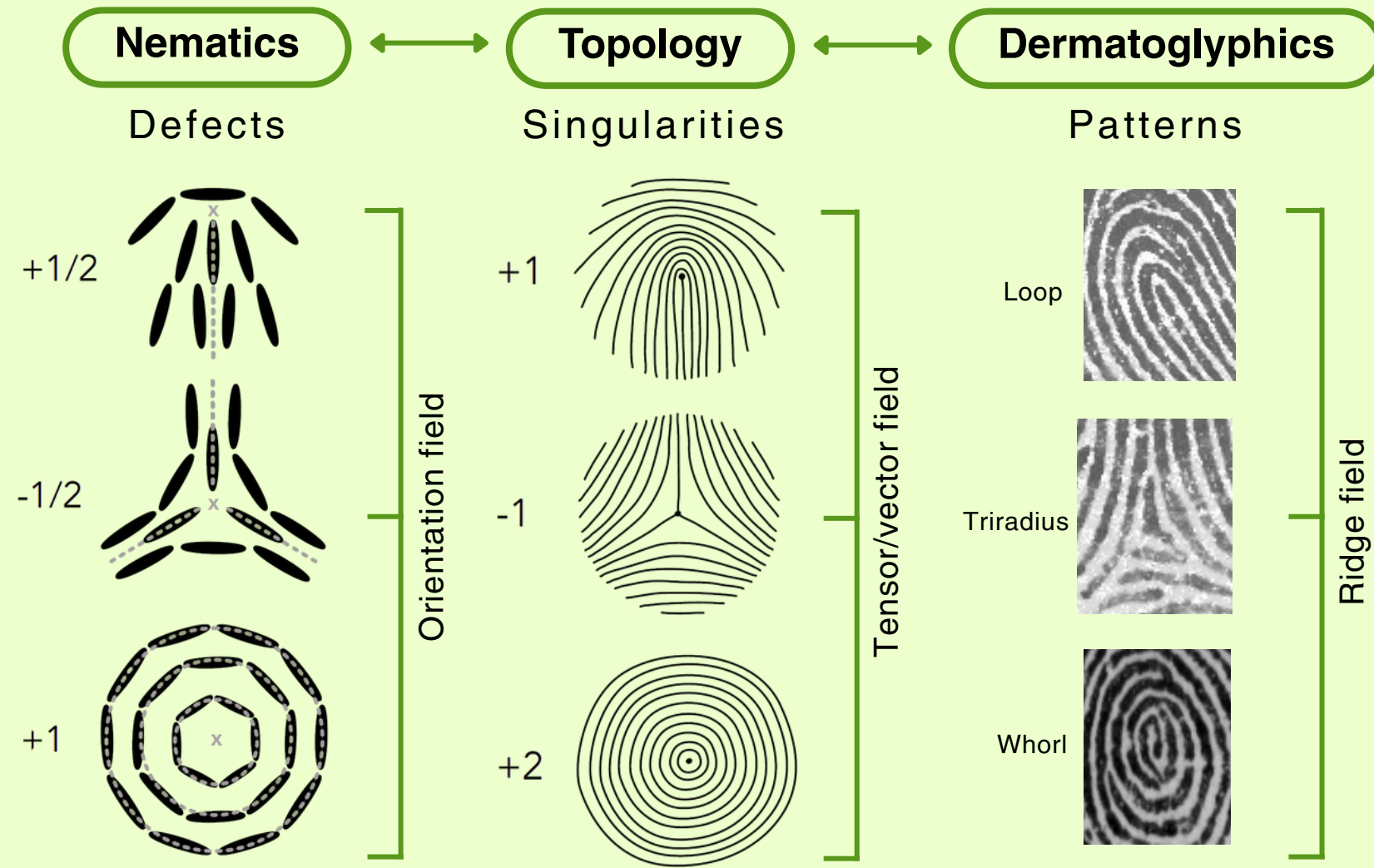


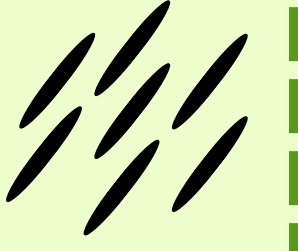
Fig. 2 - Fingerprints as nematic topologies. Correspondence between nematic liquid crystal **defects**, topological **singularities**, and classical fingerprint **patterns**. Loops, triradii, and whorls correspond to characteristic topological structures within an underlying orientation field, suggesting that fingerprints can be understood as **frozen nematic fields**

## AIMS & METHODS

To test whether fingerprint patterns can be understood through nematic topological constraints

### INTERPRET

- Fingerprints represented as **orientation fields**
- Defects and singularities identified from **ridge geometry**



- Poincaré–Hopf theorem** [3] applied to fingerprint domains
- Constraints derived from **domain geometry** and **boundary winding**

### PREDICT

### VALIDATE

- 133 fingerprints classified by **defect configuration**
- Predictions compared against **observed patterns**



## THEORETICAL PREDICTION

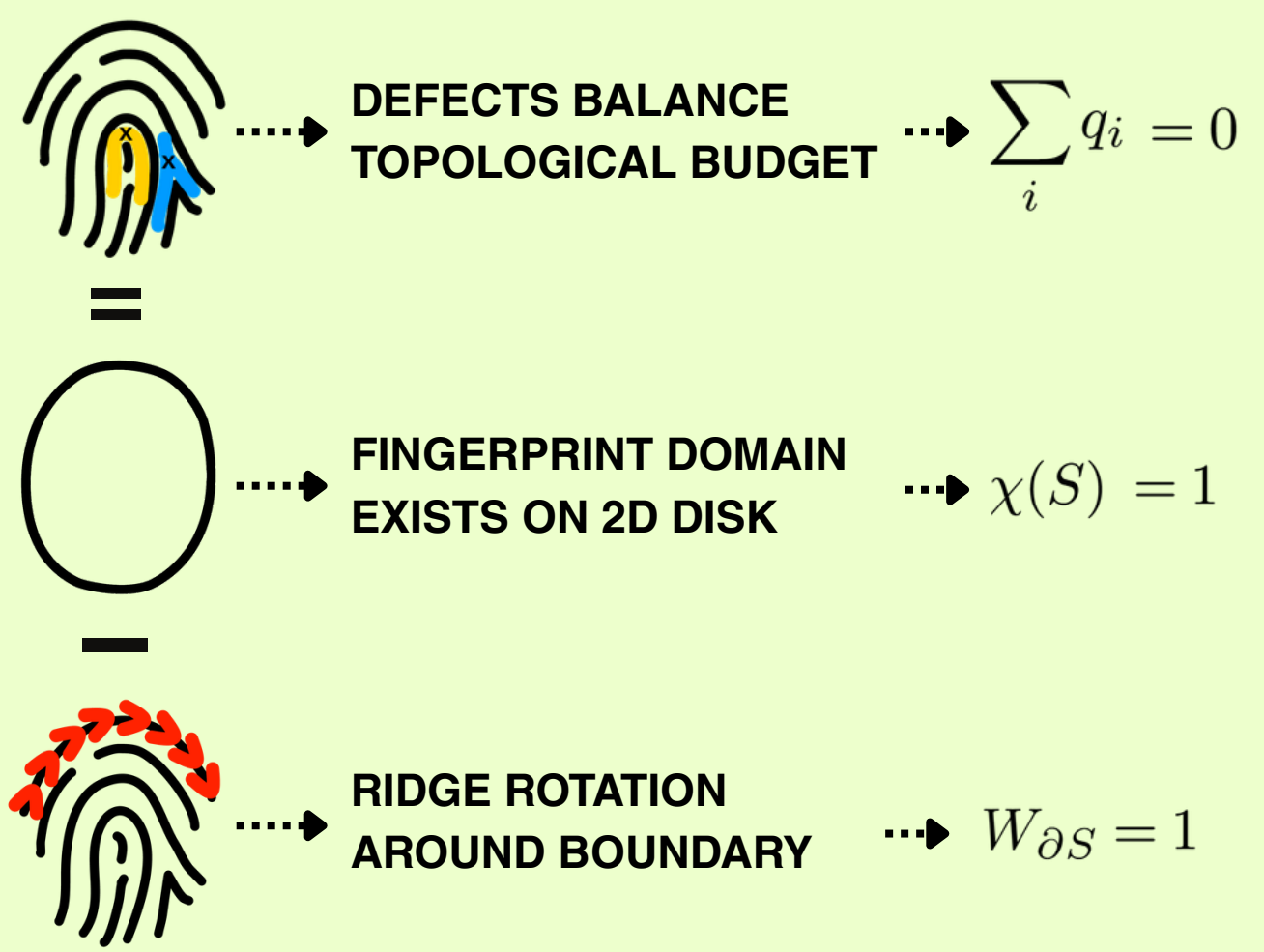


Fig. 3 - Applying the Poincaré–Hopf theorem [3] to fingerprint orientation fields predicts the **permissible combinations** of loops, whorls, and triradii expected in real fingerprints

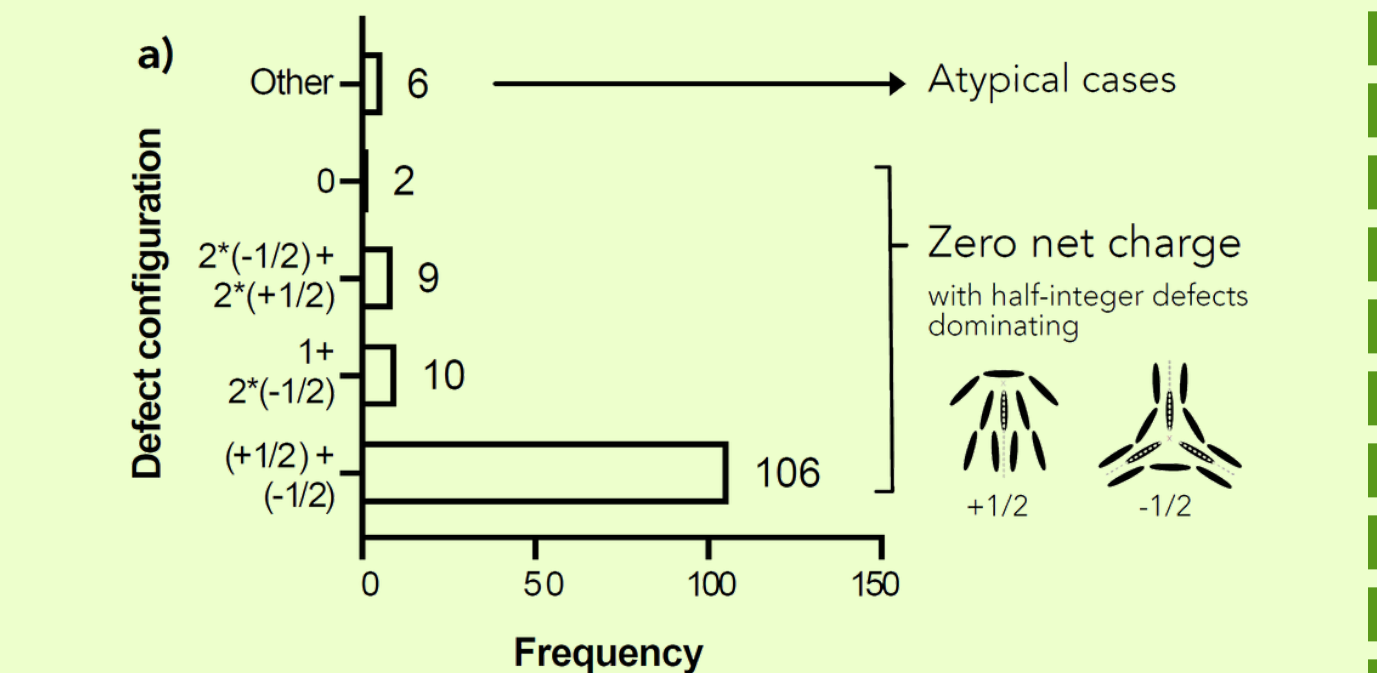
## CONCLUSIONS

- Fingerprints are consistent with **nematic topologies**
- 95.5%** of fingerprints satisfy the **predicted charge neutrality**
- Developmental patterns may reflect **universal topological principles** across biological systems



## REAL FINGERPRINTS

95.5% of fingerprints show charge neutrality



Net charge is sensitive to boundary winding

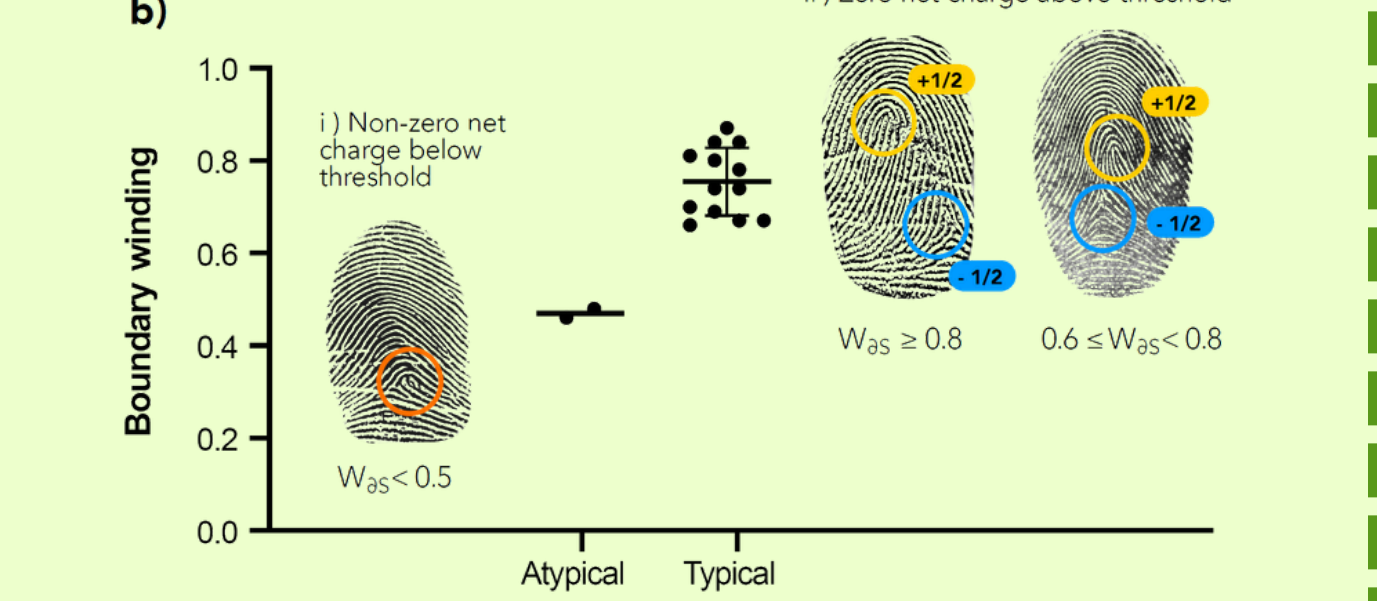


Fig. 4 - Analysis of 133 real fingerprints [4]. a) Distribution of defect configurations, 95.5% of fingerprints showed pattern **charge neutrality**. b) Boundary winding analysis (n = 15) suggests charge neutrality emerges above a **critical winding threshold** ( $W < 0.6$ )

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