# Sparse coding predicts a spectral bias in the development of V1 receptive fields


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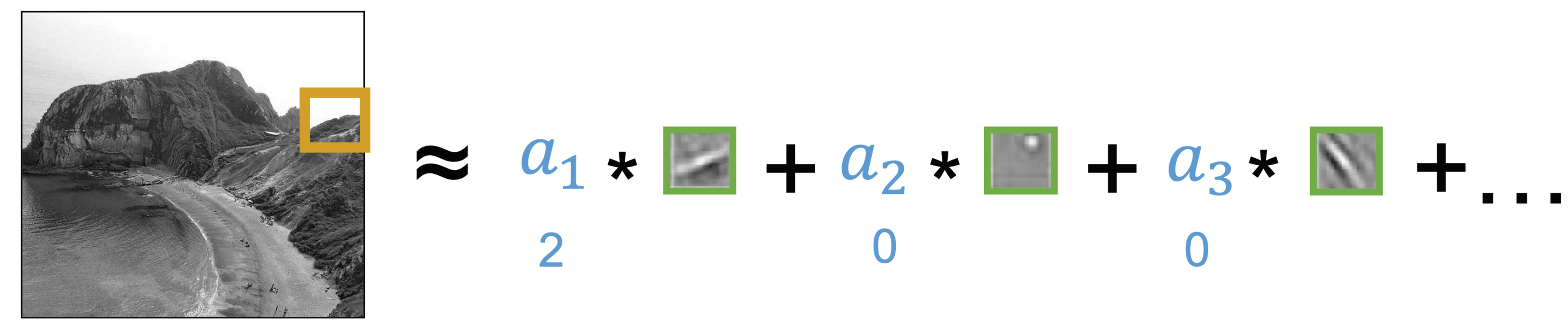
## Introduction

Sensory neurons learn internal representations of the natural world known as **receptive fields (RFs)**. In the visual cortex, RFs are tuned to specific frequencies, orientations, and spatial locations.[1] Are certain features learned by the visual cortex earlier in development than others, and if so, can we understand from first principles why this might be?

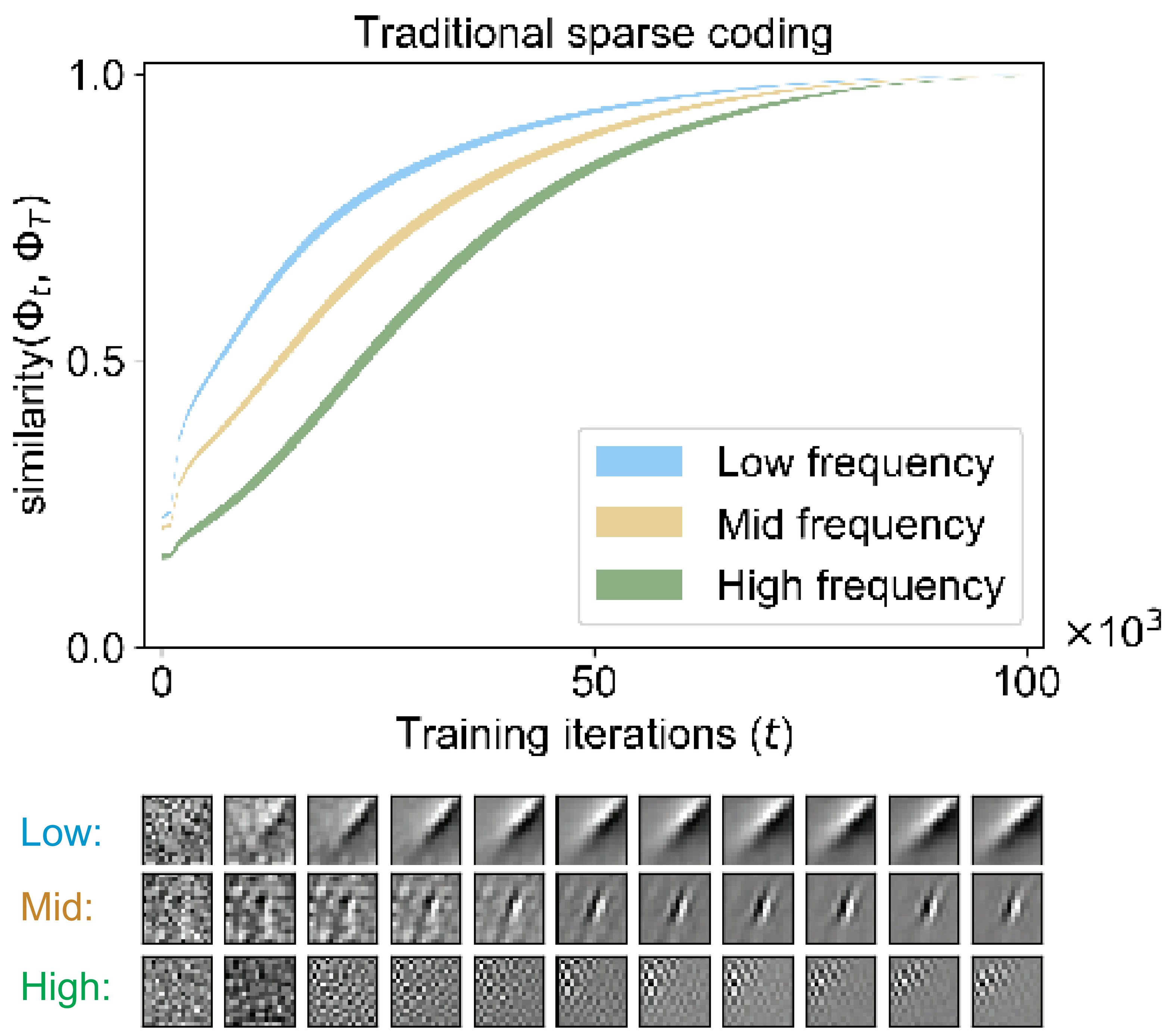
**We aim to 1) determine whether there is a temporal order to how differently tuned RFs develop, and if so, 2) assess which computational principles play a role in determining this order.**

## Model

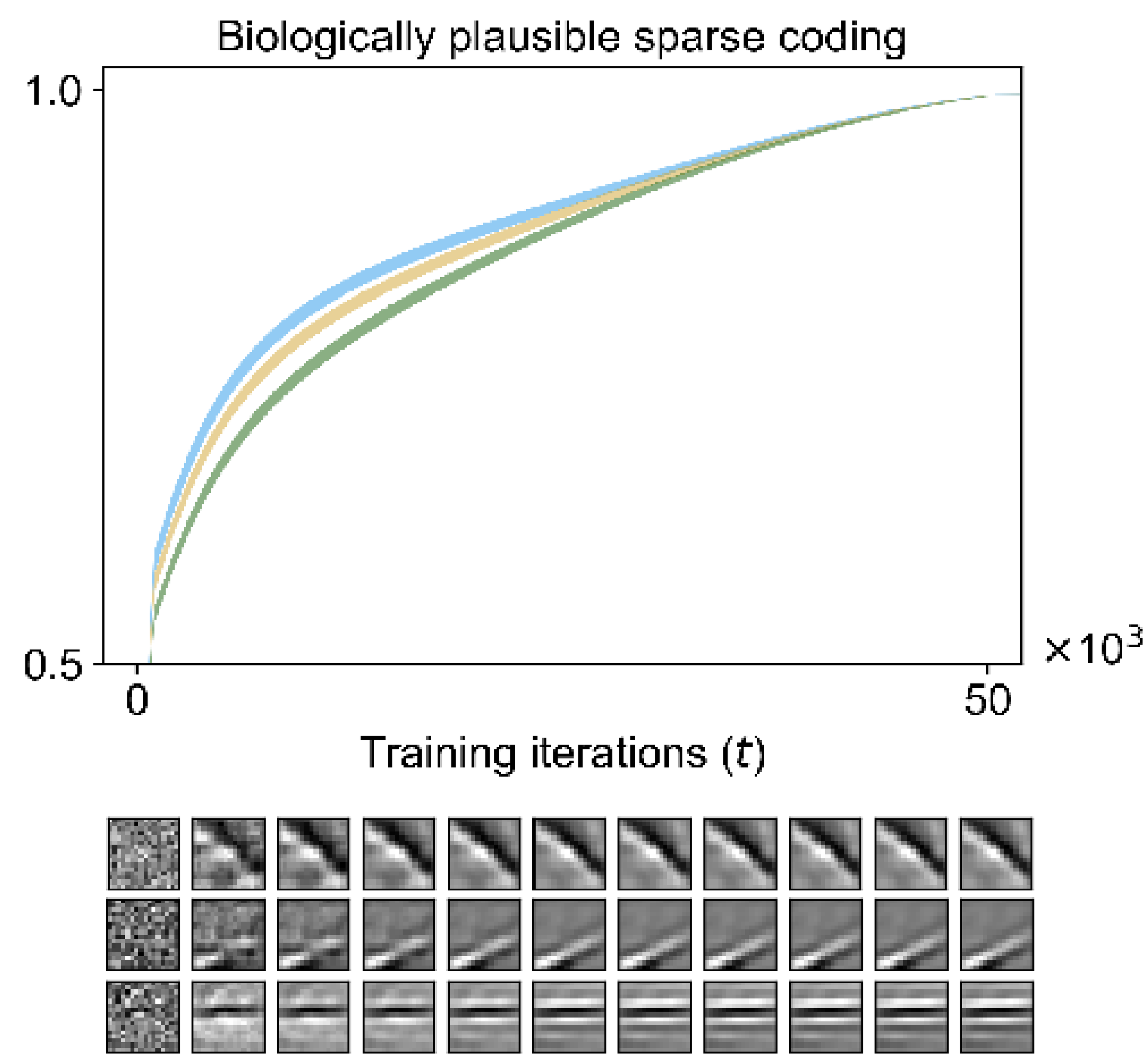



**Sparse coding:** Find representations of data in terms of sparse activities.[1]

## Model results

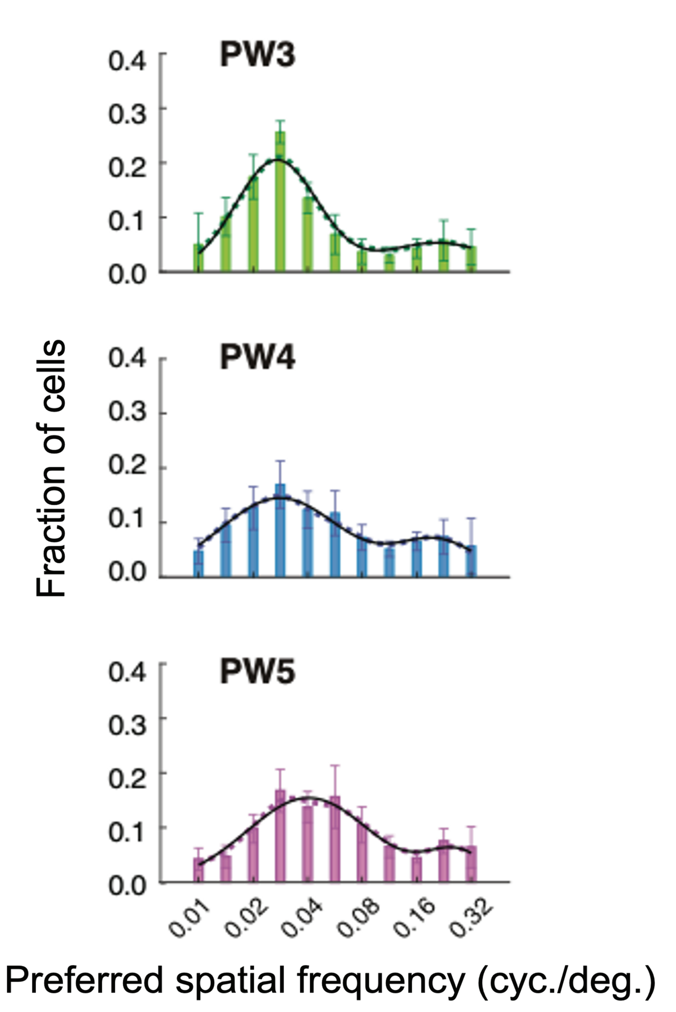



Sparse coding models learn lower frequency RFs earlier in training. The extent to which a RF is learned at a given timepoint *t* is measured by cosine similarity to its final learned shape.



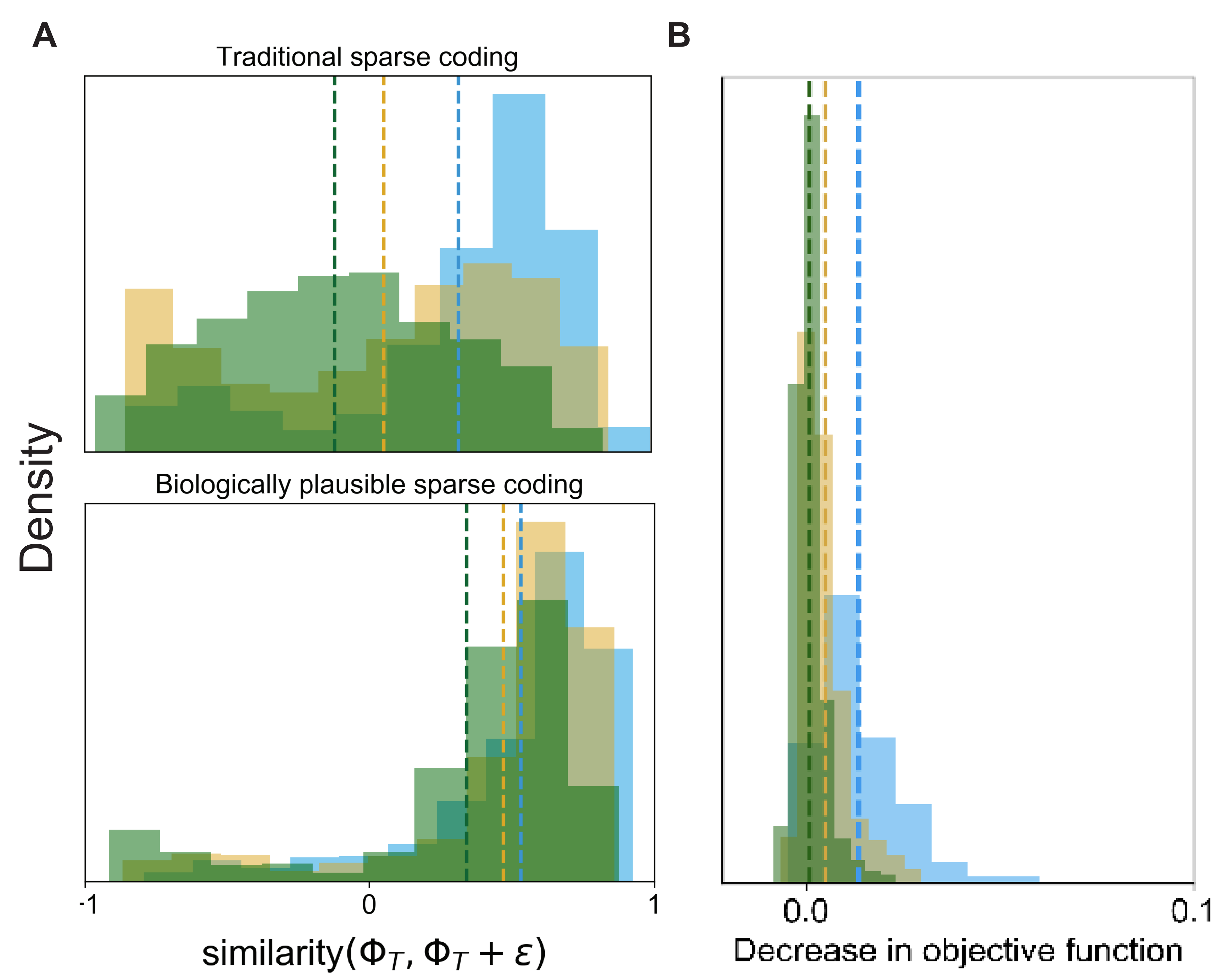

A biologically plausible implementation of sparse coding using spiking neurons and synaptically local learning rules also learns lower frequency RFs earlier in training.

## Comparison to biological data




The model prediction is consistent with experimental evidence, which shows that visual neurons beceome more attuned to higher spatial frequencies over the course of development. In particular, the overall distribution of optimal tuning of V1 neurons in mice shifts towards higher spatial frequencies from postnatal weeks 3-5 (figure adapted from Nishio et al. 2021).[2]

## Candidate explanations for spectral bias




**A** Distribution of perturbations to RFs under a 1-pixel phase shift $\varepsilon$ shows that higher frequency RFs are more sensitive to small changes in parameters, suggesting they may require more information to specify accurately.

**B** Swapping in lower frequency RFs into a randomly initialized model yields better model performance than swapping in higher frequency RFs, suggesting early development of low frequency RFs leads to faster optimization.

## Summary


**Sparse coding models predict that lower frequency receptive fields emerge earlier in development, and this is consistent with biological data. This phenomenon may be due to the spatial complexity of higher frequency features, which take longer for sparse coding models to learn.**


## References


1. Olshausen, BA & Field, DJ (1996). Emergence of simple-cell receptive field properties by learning a sparse code for natural images. *Nature, 381 (6583), 607-609.*
2. Nishio, N et al. (2021). The role of early visual experience in the development of spatial-frequency preference in the primary visual cortex. *The Journal of Physiology, 599 (17), 4131-4152.*