**Specific aims**

The retina plays an important role in early visual processing by separating visual information into multiple cell types that each process specific visual information. These pathways do not encode all information in visual scenes, but instead focus on encoding specific patterns of stimuli. While we know what visual information is encoded by these neurons, the physiology itself cannot tell us *why* the receptive fields of neurons are organized in this way. We want to make theories that explain retinal function, and such theories need corresponding quantitative models that can make predictions about how the retina is organized. Successful theories should be able to explain many properties of retinal ganglion cells (RGCs), such as why RGCs are separated into multiple cell types with each cell type having neurons tiling the entire retina at different spatial locations to form a mosaic.

The efficient coding hypothesis is one of the most successful theories in this vein, which states that the retina should remove redundancies to maximize the amount of information transmitted to the brain through the finite-size optic nerve. This hypothesis can explain many features of retinal encoding such as center-surround receptive fields and ON-OFF pathways1-5. Previous work from my lab has succeeded in using efficient coding to explain why neurons are divided in different cell types that each form its own mosaic. These models explain the anti-alignment between ON and OFF mosaics, as well as how cell types process different spatial and temporal frequencies. However, these models do not explain how the retina processes chromatic information or why RGCs can be direction-selective. . My project will make such efficient coding predictions for the encoding of color (Aim 1) and motion (Aim 2)by building an efficient coding model that can process multiple correlated channels. . By comparing these results with experimental data from the Field Lab at UCLA, we will learn how many properties of retinal receptive fields can be accounted for by efficient coding principles.

**Aim 1: Expand efficient coding models to encompass chromatic information**

Encoding of color starts at the level of cone photoreceptors in the retina, which come in three types: Long (L), Medium (M), and Short (S), roughly encoding red, green and blue stimuli, respectively6. Most retinal ganglion cells (RGCs) in the fovea are color-opponent, meaning they are excited by one color and inhibited by another. Color-opponent cells can be separated into two types: Midget cells, which encode red-green opponency in the fovea, and bistratified cells which encode blue-yellow opponency. While previous efficient coding models have successfully explained color-opponency7, 8, they have failed to explain the separation of color processing into midget and bistratified cells. More specifically, they fail to explain why midget cells represent 70-80% of RGCs, despite red-green opponency rarely occurring in natural images. Previous models also fail to explain why the retina only has an ON but not an OFF pathway to encode blue-yellow opponency. My machine learning model has three key differences that put me in an advantageous position to explain such phenomena. First, because my model assumes a limited number of neurons, it is successful at simulating different cell types that each form a mosaic9, 10. Second, my model has an output nonlinearity, which allows me to make different predictions for the ON and OFF pathways. Third, my model takes natural images as input, which might be crucial to replicate details about retinal processing. Using this model, I will focus on trying to explain two major findings: 1) Why the ON-OFF asymmetry in bistratified cells occurs, and 2) why midget cells represent most neurons in the fovea despite encoding events that rarely occur in natural images. Completion of this aim will test whether a good efficient coding model can help us understand how cell types are structured to encode chromatic information.

**Aim 2: Expand efficient coding models to explain motion-selectivity in RGCs**

Visual scenes typically involve movement, either from motion of objects through the visual scene or optic flow from our own movements. The encoding of visual motion starts as early as the retina, with several subtypes of retinal ganglion cells (RGCs) having stronger responses to one direction of motion than to its opposite11, 12. The major type of motion-encoding RGCs are ON-OFF direction-selective ganglion cells (DSGC)13, which are divided into four subtypes that respond preferentially to each of the four cardinal directions12. I hypothesize that these populations emerge naturally from efficient coding principles. Previous models assumed independent spatial and temporal receptive fields, which are incapable of capturing motion in a specific direction because the spatial receptive fields are static across time. Instead, I will build an efficient coding model that allows for fully general spatiotemporal receptive fields. I will then test whether this model, trained to efficiently encode natural movies, successfully replicates ON-OFF DSGCs that only encode the four cardinal directions12.. Completion of this aim will enlighten us as to whether efficient coding can explain the diversity of motion-encoding cell types in the retina.

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