One of the primary goals in neuroscience is to figure out simple principles that explain how nervous systems are organized. Barlow (1961)(Jun, Field and Pearson 2022) proposed one of the most successful theories in this vein, which states that sensory systems should remove redundancies in their inputs to optimize the information they process. This *efficient coding hypothesis* provides us with a mathematical framework to understand how neurons *should* encode information, which can then be experimentally tested against how neurons *actually* do so. Over the past 60 years, efficient coding has successfully explained many experimental findings in different sensory modalities such as vision, audition and touch. In particular, this hypothesis has been successful early on in the retina. Recent work has carried this further by replicating the receptive fields of retinal ganglion cells (RGCs) across a population of neurons. My work will extend this even further by replicating how the retina integrates redundant inputs, either across different color channels (Aim 1) or across time (Aim 2). These results will allow us to understand how much of retinal physiology can be explained by efficient coding principles.

How the retina processes visual information follows a well-known structure. Photoreceptors first transform light from the outside world into electrical activity. Photoreceptors then send this information to bipolar cells, and bipolar cells send this information to retinal ganglion cells (RGCs). These RGCs are the visual inputs to the brain, and send projections to the thalamus through the optic nerve. RGCs already pre-process the information they receive from photoreceptors, by having center-surround receptive fields. These receptive fields are circular and separated into two different regions, an excitatory center and an inhibitory surround. Early theoretical work (citation) has explained how this center-surround organization arises from efficient coding principles, both for achromatic and for color inputs.

This early work made many simplifying assumptions to make the problem mathematically tractable. Because of their simplicity, such models fail to explain the details of retinal physiology. More recent work has leveraged machine learning to make efficient coding models with more biologically realistic constraints, such as non-linear output responses and a limited number of neurons. These new models explain why RGCs are separated into different subtypes, with neurons within a subtype forming a ‘mosaic’ that tiles the entire retina. However, the inputs to RGCs are much more complex than static achromatic images – RGCs receive input images from multiple color channels, which are usually in motion. While efficient coding can predict how the retina should process achromatic stimuli, its predictions for color and motion processing – two crucial aspects of natural stimuli – are still unknown. To close this gap, I will expand the current efficient coding algorithms to replicate how RGCs process color information (Aim 1) and motion (Aim 2). I will collaborate with Greg Field from UCLA to make use of his expertise in retinal physiology for our efficient coding models. This collaboration also opens the possibility to test the predictions of our model against new experimental data.

**Aim 1:** Test whether efficient coding can explain how the retina encodes chromatic information

Color is a crucial aspect of how we perceive the visual world. Encoding colors starts at the level of cone photoreceptors, which come in three types – Long (L), Medium (M) and Short (S) –which roughly encode red, green and blue stimuli, respectively. This color information is then encoded by RGCs, with different types integrating cone inputs differently. Most (~70%) of RGCs are midget cells, which encode a combination of L and M cones. In the fovea, these cells are ‘red-green opponent’ and encode a contrast between L and M inputs. In the periphery, these midget cells are not red-green opponent but instead sum L and M cones inputs. Why midget cells use different coding strategies for the fovea and for the periphery is still unclear. We hypothesize those different strategies have to do with the ratio between RGCs and cones in the fovea versus the periphery. While the periphery has more cones than RGCs, the opposite is true for the fovea, with approximately 3 RGCs for every cone. Here we will test that hypothesis by building an efficient coding model for chromatic natural images. The inputs to this model will be the LMS cone responses to a series of natural images. We will then filter these responses through three different spatial filters (one for each cone), followed with an output non-linearity. The weights of the filter will be fit to optimize the mutual information between the cone inputs and the RGC outputs. Consistent with efficient coding principles, there will be a constraint on the total firing rate across all neurons. To model the center versus the periphery, we will change the number of outputs RGCs relative to the number of input cones. Preliminary results suggest that if we keep the RGCs-cone ratio to 1:1, efficient coding predicts that L and M inputs should be summed. We will next see if we can replicate chromatic receptive fields in the fovea by building efficient coding models with a 3:1 RGCs-cones ratio. We will also test whether we can replicate receptive fields from RGC types other than midget cells, such as parasol and bistratified cells. test whether efficient coding can accurately explain how the retina encodes chromatic information.

**Aim 2:** Test whether efficient coding models can explain why some RGCs are motion-selective

Visual scenes are typically in motion, either because of objects moving or optic flow from our own movements. While the encoding of visual motion has historically been thought to be achieved in the primary visual and medial temporal cortices, it is now known that motion-encoding starts as early as the retina. Several subtypes of retinal ganglion cells (RGCs) are direction-selective, each of which responds most strongly to object motion in a different preferred direction. However, the efficient coding predictions for how RGCs should encode motion is currently unknown. Making such predictions requires building a spatiotemporal efficient coding model, which is technically challenging. My lab previously accomplished this feat by making specific assumptions about the structure of spatiotemporal receptive fields. More specifically, we assumed that how receptive fields change across space is independent from how receptive fields changes across time; an assumption termed “space-time separability”. A limitation of this model is that it fails to replicate direction-selectivity. We strongly suspect this limitation is due to the assumption of space-time separability. To test whether we can explain motion-selectivity in RGCs from efficient coding principles, I will build an efficient coding model that estimates receptive fields that are not space-time separable. This model will be conceptually similar to the one from Aim 1, where the inputs to model RGCs come from multiple channels, each of which represents a different latency. Completion of this aim will solve efficient coding for motion in natural images, which we will be able to compare to experimental data from both the literature and from our collaboration with Greg Field at UCLA.