One of the primary goals in neuroscience is to figure out simple principles that explain how systems are organized. Barlow (1961) proposed one of the most successful theories in neuroscience, which states that sensory neurons should be efficient – they should optimize the amount of information they process, while also keeping their firing rates to a minimum. This *efficient coding hypothesis* provides us with a mathematical framework to understand how neurons should encode information, which can then be verified experimentally.

Efficient coding states that sensory information must be compressed to reduce the overall number of spikes. This compression occurs by encoding unexpected events, or discrepancies between inputs that are correlated. Information is lost during compression, which means the brain must compromise between encoding as much information as possible and saving energy. This information cost increases as a function of input correlations, which also influences the optimal efficient coding strategy. While a lot of work has been done to understand how sensory neurons should encode inputs that are moderately correlated, how sensory neurons should efficiently encode different inputs that have very weak discrepancies is still unclear.

To study this question, I will use efficient coding models on natural images and compare it to neurons in the early visual system. The efficient coding hypothesis has been especially successful at replicating experimental data in the retina, where it explains why retinal ganglion cells (RGCs) have center-surround receptive fields and why these neurons encode color-opponency. Efficient coding also explains why RGCs are organized into different functional types, with each type tiling the entire retina to form a mosaic. My lab recently found that whether different mosaics should be aligned or anti-aligned depends on whether the internal noise levels of RGCs is low or high (Jun, Field & Pearson, 2021). For my project. My central hypothesis is that how RGCs integrate information follows an optimal efficient coding strategy, even with strong input correlations across different color channels or across time.

**Aim 1:** Determine the optimal efficient coding strategy across correlated color channels

Information in natural images is mostly achromatic, and differences between shades of red and green represent very little of the information. However, how the retina works seems to contradict that principle: Midget cells consist most (80%) of RGCs and encode red/green opponency, while parasol cells, which encode achromatic information, only represent a small fraction (10%) of RGCs. *My working hypothesis is that we can reconcile these two principles and show that encoding visual information with a high proportion of midget cells is efficient.*

**Aim 2:** Determine the role of motion in optimally encoding natural movies

My lab previously developed a spatiotemporal efficient coding model, where we optimize the receptive fields of neurons in both space and time. We found that as we increase the number of neurons, new cell types with higher temporal and lower spatial frequencies emerge – a finding analogous to retinal parasol cells. However, this model assumed that receptive fields are spatiotemporally separable; that is, the spatial structure of a receptive field does not change across time. While motion is an important feature of natural movies, such an assumption prevents model neurons from learning the direction of motion.

Successful completion of both aims will provide a mathematical understanding how sensory systems should efficiently encode correlated inputs. The immediate impact of this work is an explanation as to why retinal ganglion cells have specific receptive fields. The long-term impact of this work is getting us one step closer to understanding general principles about how sensory systems work.

John’s advice:

Color is about how we optimize different input channels

So is motion?

Details about midget cells (etc) goes in background, not in specific aims

Present my project as something very general,

Core: My project is about understanding how efficient coding works with different correlated channels

Both correlated noise, color and motion fit in that problem

Efficient coding has particularly been successful in vision

Our lab showed that efficient coding model can be applicated in more complex scenarios to understand mosaics. Allows us to answer new questions

Most theoretical papers in vision assume that mosaics are infinite, assume linearity, etc.

Predictive coding in retina: Stephanie Palmer

Interesting idea: Some redundancy is useful because of noise, even though