II. **Mechanistic** Model of Receptive Fields
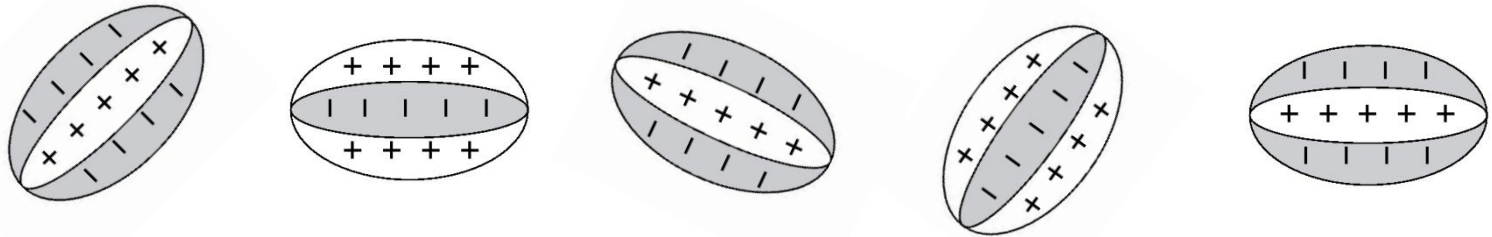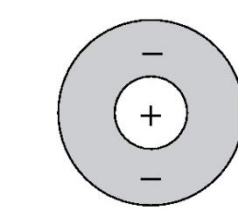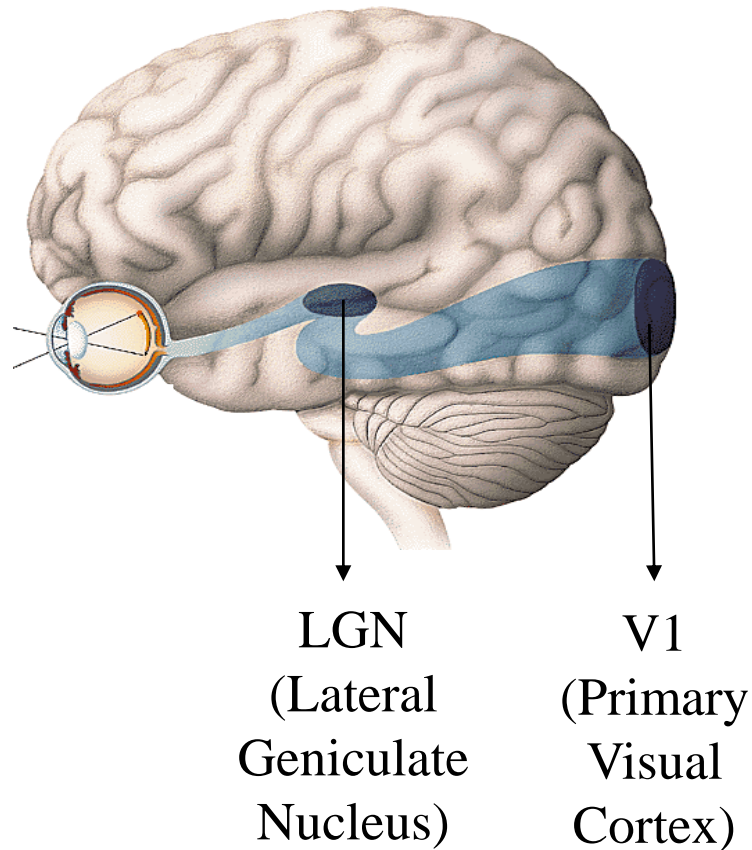
✦ The Question: *How* are receptive fields constructed using the neural circuitry of the visual cortex?
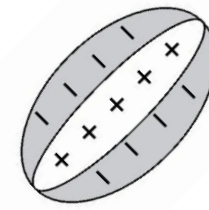
How are these *oriented* receptive fields obtained from *center-surround* receptive fields?
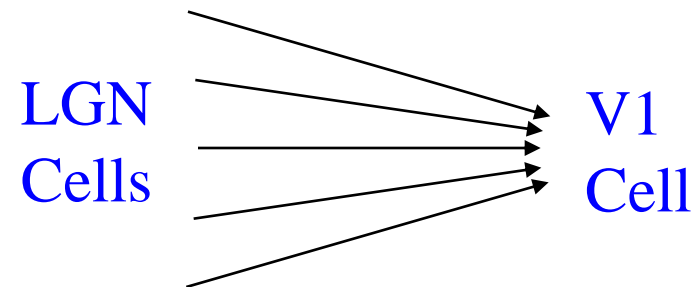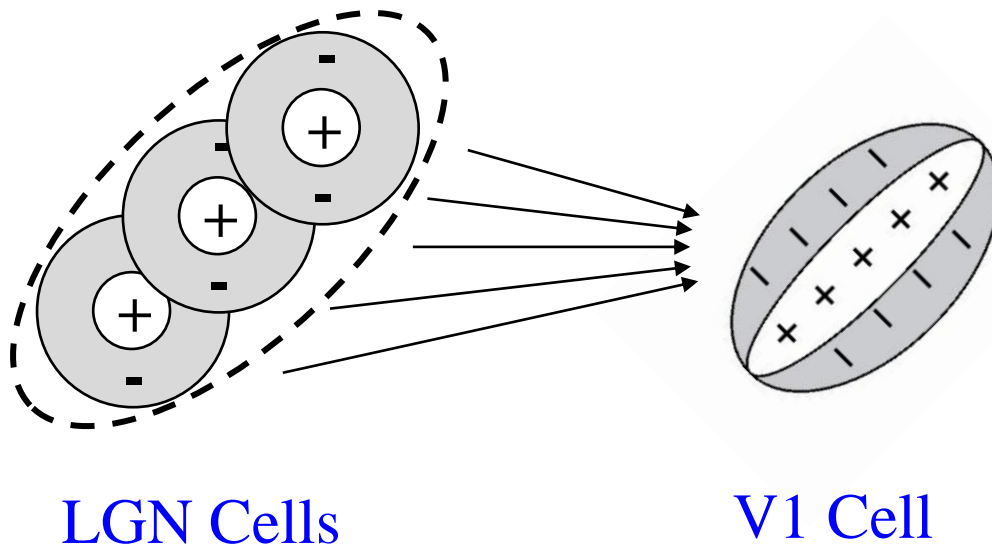
II. Mechanistic Model of Receptive Fields: V1

LGN RF

V1 RF

LGN
(Lateral
Geniculate
Nucleus)

V1
(Primary
Visual
Cortex)

LGN
Cells

V1
Cell

II. Mechanistic Model of Receptive Fields: V1

LGN Cells

V1 Cell
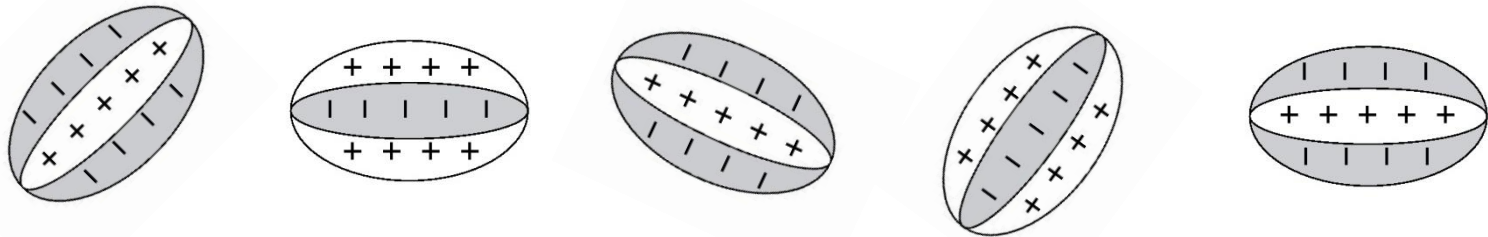
Model suggested by Hubel & Wiesel in the 1960s: V1 RFs are created from converging LGN inputs

Center-surround LGN RFs are *displaced along preferred orientation* of V1 cell

This simple model is still controversial!

III. Interpretive Model of Receptive Fields

✦ The Question: *Why* are receptive fields in V1 shaped in this way?

What are the computational advantages of such receptive fields?

III. Interpretive Model of Receptive Fields

- ✦ Efficient Coding Hypothesis: Suppose the goal is to *represent images as faithfully and efficiently as possible* using neurons with receptive fields $\mathbf{RF}_1$, $\mathbf{RF}_2$, etc.
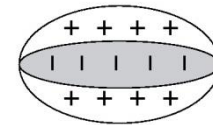
- ✦ Given image $\mathbf{I}$, we can reconstruct $\mathbf{I}$ using neural responses r_1, r_2 …:
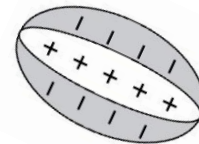
$$\hat{\mathbf{I}} = \sum_i \mathbf{RF}_i r_i$$

- ✦ *Idea*: What are the $\mathbf{RF}_i$ that *minimize* the total squared pixelwise errors between $\mathbf{I}$ and $\hat{\mathbf{I}}$ and are as *independent* as possible?
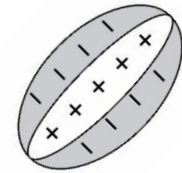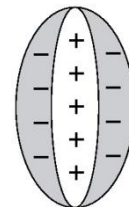
$\mathbf{RF}_1$

$\mathbf{RF}_2$

$\mathbf{RF}_3$

$\mathbf{RF}_4$

III. Interpretive Model of Receptive Fields

✦ Start out with random **RF**$_i$ and run your efficient coding algorithm on natural image patches

Natural Images
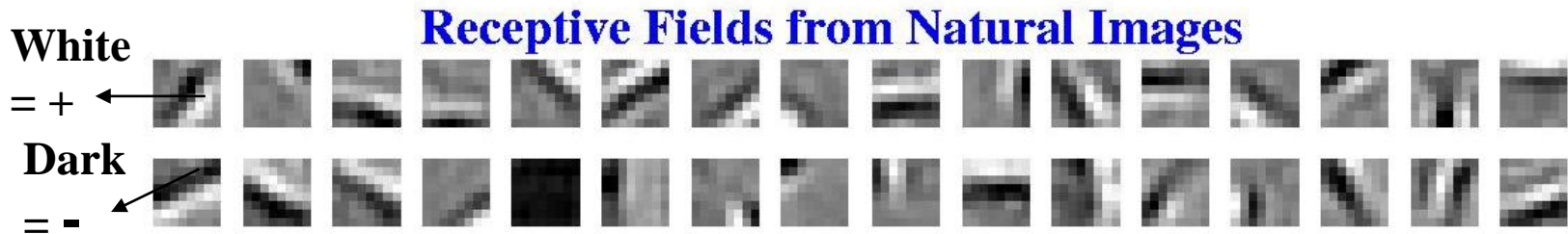

□ Receptive Field Size
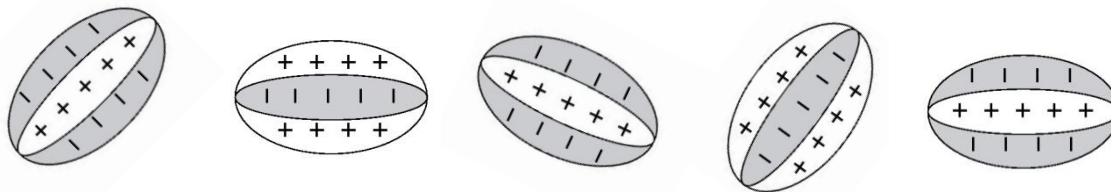
Sparse coding   ICA   Predictive coding

(Olshausen & Field, 1996; Bell & Sejnowski, 1997; Rao & Ballard, 1999)

III. Interpretive Model of Receptive Fields

Receptive Fields from Natural Images

White
= +

Dark
= -

Receptive Fields in V1

Conclusion: The brain may be trying to find *faithful and efficient* representations of an animal's natural environment

We will explore a variety of *Descriptive*, *Mechanistic*, and *Interpretive* models throughout this course.

But before we do that…

Neurobiology 101:
Introduction to neurons, synapses, and brain regions

[Next Lecture]