V1 Cortex and the Receptive Field Hypothesis
Spatial selectivity in V1 cortex

• Receptive fields as an explanation
  – Orientation selectivity
  – Spatial frequency selectivity
  – Size tuning

• Receptive field hypothesis fails: what new explanations?
Sine gratings: orientation, spatial frequency, contrast
Spatial properties derive from the cortical receptive field--an hypothesis

Hubel-Wiesel MOVIES
Ohzawa MOVIES
Ohzawa MOVIES
Orientation selectivity and the feedforward model
Feedforward hypothesis and receptive field hypothesis go together.

Do they describe V1? Evidence from diversity, pharmacology, dynamics, “Oscillations”.
Selectivity of feedforward input (from Sompolinsky et al, 1997)
Diversity in bandwidth

![Graph showing the distribution of bandwidth with N=308](image-url)
Orientation Selectivity
(Measured by the “circular variance” of the tuning curves)

\[ CV[m] = 1 - \left| \frac{\int m(\theta) \exp(2i\theta) d\theta}{\int m(\theta) d\theta} \right| \]

CV \sim 1, poorly tuned
\sim 0, very selective

A measure of “height-to-trough” of the orientation tuning curve
Diversity in circular variance

N=308

# Cells vs. Circular Variance
Orientation selectivity in different cortical layers implying that ori selectivity starts in layer 4c.
The effect of bicuculline on orientation tuning ==> role of GABA

Figure 8. Averaged tuning curves of visual response of orientation-selective cells (OSI \geq 0.50) in each layer
Spatial Frequency Tuning data reinforce the conclusion from Ori-tuning: that nonlinear cortical inhibition (suppression) is important for spatial-feature selectivity.
Spatial frequency tuning - LGN (DeValois & DeValois 1988)
SF tuning-V1 cortex (DeValois & DeValois 1988)
Strong correlation between ori and sf tuning
NYU Egalitarian model --> untuned suppression for ori tuning
Spatial frequency and orientation tuning in a model of V1

Zhu et al
Correlation between sf and ori selectivity in the inhibition-model of Zhu et al.
The correlated factor: cortical inhibition

Theory tells us that cortical inhibition would be able to explain orientation selectivity and its correlation with spatial frequency selectivity. But how do we find out more about this cortical inhibition? --dynamics experiments.
Increment counter corresponding to this orientation by +1
Ori dynamics suggests

Untuned Suppression revealed by dynamics experiment

Ori dynamics suggests

Untuned Suppression

Tuned Suppression
Orientation tuning dynamics of firing rate--illustrating inhibition of responses to non-preferred orientations (Celebrini et al 1993)
Another line of evidence: oscillations

feedforward networks don’t usually have “oscillations” or damped periodic activity. But V1 does--in the gamma band mainly.
Gamma Band peaks in LFP spectrum grow with stimulus size
Andy Henrie, Ray & Maunsell (2010)
We think that recurrent excitatory-inhibitory networks in visual cortex are responsible for sharp orientation and spatial frequency selectivity.

Bu then we found other problems with receptive fields--they only explain what is happening in layer 4c, in straightforward mapping experiments.
Comparison of spatial maps with different sets of stimuli

Similar in 4C but wildly different in 2/3
A new view of V1 cortex

Goodbye to the Receptive Field Hypothesis --for V1

Feedforward, receptive-field hypothesis not adequate (even for layer 4C cells)

Cortico-cortical connections more important for all other layers

Need recurrent models of cortex--consistent with functional connectivity.