Models of Receptive Fields: Converting electrical activity of neuron to an audio signal
↳ allows to immediately + easily tell when a neuron is active.

3 Forms of Computational Models

- Descriptive Models
  - How do neurons respond to external stimuli
    - how do we describe this quantitatively w/ "neural encoding" model
  - How can we extract info from neurons (decoding)
- Mechanistic Models of Brain Cells + Networks
  - how can we simulate the behaviour of a single neuron on a computer?
  - how can we simulate a network of neurons?
- Interpretive (Normative) Models
  - Why do brain circuits operate the way they do?
  - What are the computational principles underlying their operation?

Recommended Textbooks: Theoretical Neuroscience : Comp. + Math. Modelling

Goals: 1. Quant. describe what Biological neuron/s is doing
network of neurons
given experimental data

2. Simulate on Comp behaviour of neuron+ networks

3. Formulate Computational Principles underlying operations of neuron+ networks in brain

Descriptive Models

Comp Neuro: • explain in computational terms how brains generate behaviour?

• gives tools + methods for
  • characterizing what nervous systems do
  • determining how they function
  • understanding why they operate in particular ways

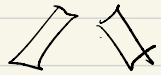
$\Leftrightarrow$

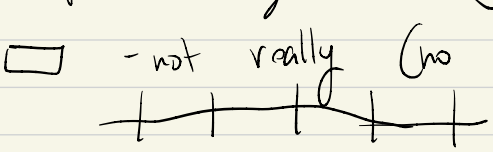
Descriptive Model (What)
Mechanistic (How)
Interpretive (Why)

Models of Receptive Fields

Hubel-Weasel exp

ex: Stimulus → cat

Cat's neuron responded strongest to bar of light diagonal 

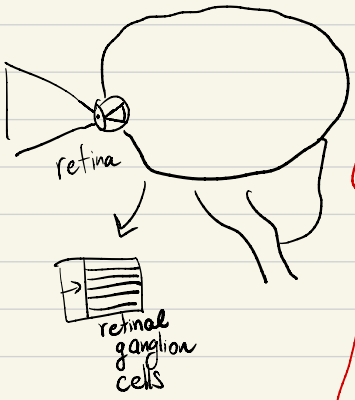


In computational terms, this model is defined by a function - converting stimulus (indep. var) into electrical response (dependent)

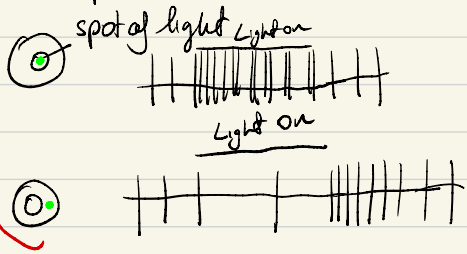
Freq. of spike: f(Light bar's orientation)

Receptive Field: best orientation & illicit maximal response

Descriptive Model



Receptive Fields in Retina



Thus Center-Surround Receptive Fields in Retina

On-Center
Off-Surround
Receptive Field

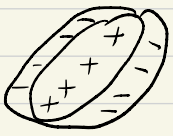
counterpart:

Off-center
on-surround
receptive field

info passage

retina → Lateral Geniculate Nucleus → Primary Visual Cortex

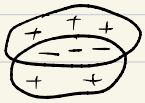
In Cat experiment:



Oriented receptive field of a neuron in primary visual cortex

Descriptive Model of receptive Field

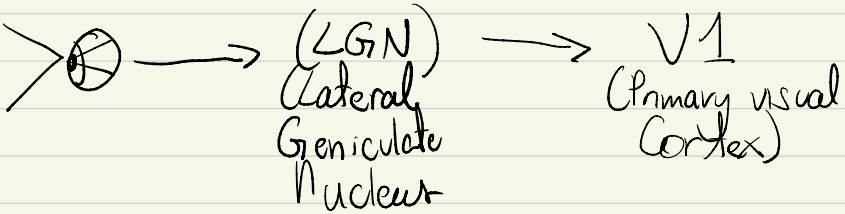
Other examples:



We will later learn how to quantify using reverse-correlation

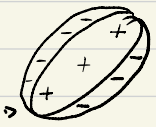
Q: How are these oriented fields obtained from center-surround receptive fields?

A: Mechanistic Model



LGN RF (Receptive field)

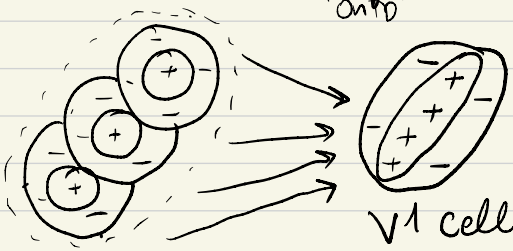
V1 RF



Answer in anatomy

(LGN cells)
(not injective process)
"and"

(V1 cell)



V1 cells

Center-surround LGN RF are created by converging LGN inputs

* controversial model

Mechanistic model (explains how observed data is there)

∃ rec. input not accounted for

Interpretive Model: Why are receptive fields in V1 shaped in this way?

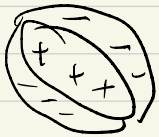
(equivalent too) What are computational advantages of such receptive fields

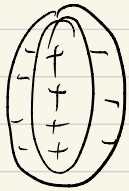
- Efficient Coding Hypothesis: Suppose the goal is to represent images as faithfully + efficiently as possible using neurons w/ receptive fields $RF_1, RF_2, \ldots$

- Given Image I, we can reconstruct I using neural response r_i

$$\hat{I} = \sum_i (\overline{RF})_i r_i$$

Idea: What are $\overline{RF}_i$ that minimize squared pixelwise errors b/w I and $\hat{I}$ and are as independent as possible (don't want many firing simultaneously)





- keep indep as poss
- minimize square error

Working toward the Interpretive Model

- Start out w/ random RF_i & run efficient coding algorithm on natural image patches

patch size of receptive field size

Types:
- Sparse Coding
- ICA
- PRedictive coding

Outcome:
- Contain white + dark, & orientations patches

Conclusion: brain may be trying to find faithful ways of interpreting visual