Higher Processing of Visual Information: Lecture II

--- April 4, 2007 by Mu-ming Poo

1. Organization of Mammalian Visual Cortices
2. Structure of the Primary Visual Cortex
   - layering, inputs, outputs, cell types
3. RF properties of V1 neurons
   a. orientation selectivity
   b. simple cell and complex cell
4. Circuitry basis of the RFs
5. Columnar Organization
   a. orientation columns
   b. ocular dominance columns

Brodmann's cytoarchitectonic maps of cerebral cortex

The organization of mammalian visual cortices
Anatomy of the primary visual cortex (area 17, V1, striate cortex)

- V1 has six layers (2 mm thick)
  - Layer 1 composed predominantly of dendritic and axonal connections, no neuronal cell bodies.
  - Layers 2/3 contain excitatory neurons which project to extrastriate cortical regions.
  - Layer 4 is divided into 4A, 4B, 4Ca, and 4Cb. Layers 4Ca and 4Cb are the major recipients of LGN projections.
  - Layers 5/6 contain excitatory projection neurons which provide feedback to LGN.
- **Blobs** – Cytochrome oxidase (CO) labeling of V1 shows CO rich regions in layer 2 & 3 termed “blobs”

Inputs from LGN

- Most LGN cells terminate in L4, M in L4Ca, P mostly in 4Cβ.
- Collaterals (branches) of M & P terminate in L6.
- K cells and some P cells terminate in blobs in L2 & 3.

Output from V1

- L2, 3 & 4B – feedforward to extrastriate areas
- L5 - feedback to pons and superior colliculus
- L6 - feedback to LGN

Within V1

- L4 → L2/3 → L5 → L6

Geniculo-cortical pathways

- **Magnocellular pathway**
  - M-type RGCs → LGN magnocellular L1 & 2 → V1 L4Ca → V1 L4B
  - L4B cells have
    - Orientation selectivity
    - Direction selectivity
    - Binocular sensitivity
    - No color sensitivity
  - M channel specialized for analysis of object motion

- **Parvcellular pathway**
**P-type RGCs → LGN parvocellular L3,4,5,6 → V1 L4C → interblob in L2 & 3**

Interblob cells in L2 & 3 have high orientation selectivity, binocular sensitivity, small receptive fields.

**P channel specialized for analysis of object shape**

**Interblob in L2 & 3**

**Koniocellular pathway**

Blue/Yellow RGCs → LGN koniocellular layer blobs in V1 L2 & 3.

**Blob cells** have monocular sensitivity, color sensitivity, concentric RF without orientation sensitivity.

**Blob channel specialized for color vision**

**Cortical Cell Types**

**Pyramidal cells** — large, pyramid shaped cell bodies, spiny dendrites, project to other areas, connect to other local neurons, all excitatory.

**Non-pyramidal cells** — small and stellate shape (spiny stellate or smooth stellate), local interneurons (~40 types), either excitatory (spiny) or inhibitory (smooth, few spines).
David Hubel (left) and Torsten Wiesel

Nonuniform representation of the visual field in V1

Cortical magnification in the fovea ----
The fovea has a larger cortical representation than the peripheral.

Cortical receptive fields

Simple cells
RFs have elongated nonoverlapping ON & OFF subregions and are tuned to orientation.
Complex cells
RFs have overlapping ON and OFF subregions and are also tuned to orientation.

Many simple and complex cells are binocular (~85%) and only respond to movement in one direction.

Simple cell and complex cell

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Circuitry basis of V1 simple cell receive fields

1. Simple cell is built up from many LGN cells
2. These LGN cells have the same center/surround structure
3. The centers of these LGN cells are distributed along a line

* you can also add a set of OFF-centered LGN cells, with their centers along the OFF subregion

Hubel & Wiesel, 1962
Circuitry basis of V1 complex cell receptive fields

- Complex cell is built up from many simple cells
- These simple cells have the same preferred orientation
- These simple cells have overlapping RFs
- These simple cells have different arrangement of subregions

### Columnar Organization

- Cells in the same column have similar properties (RF position, orientation preference, ocular dominance)

#### Orientation columns
- Olique penetration in V1
  - Preferred orientation gradually shifts
- Vertical penetration in V1
  - Same preferred orientation

#### Ocular dominance columns
- Olique penetration in V1
  - Eye dominance shift in alternating manner
- Vertical penetration in V1
  - Same eye dominance

A complete set of orientation columns is about 1 mm wide.

Monocular labeling show zebra stripes in layer IV (0.5mm wide).
The pinwheel-like orientation maps revealed by optical imaging (Blasdel & Grinvald, 1980s).

Iso-orientation maps of cat V1

Optical imaging visualizes the changes of intrinsic optical properties of neural tissues due to neuronal activity.

Orientation & direction maps of monkey V1

Orientation preference map