Lateral Geniculate Nucleus (LGN)
What happens beyond the retina?

- What happens in
  - Lateral Geniculate Nucleus (LGN) - 90% flow
  - Visual cortex
- Information Flow
  - Superior colliculus – 10% flow
Information flow in LGN
Information Organization in LGN

- Bilateral structure with six layers
- 1 million neurons in total
- Each layer receives signal from one eye
- Layer 2,3,5 receives from ipsilateral eye
- Layer 1,4,6 receives from contralateral eye
- Each eye send half information to each side LGN
Retinotopic Map

- Each location in LGN maps to a location on retina
- Receptive fields of neurons adjacent to each other in LGN have adjacent receptive fields in retina
- All the neurons on the same column across layers are sensitive to same area on the retina
Organization by Ganglion Cells

- **P-cells (parvocellular)**
  - Small medium sized cell body
  - Reaches layers 3, 4, 5, 6
  - Responsible for color, fine textures, patterns and details vision

- **M-cells (magnocellular)**
  - Larger cell bodies
  - Reaches layers 1, 2
  - Responsible for motion detection

- **K-cells (koniocellular)**
  - Largest cell bodies
  - Reaches all the six layers
### Summary of LGN Organization

<table>
<thead>
<tr>
<th>Retinal output</th>
<th>LGN cell type</th>
<th>Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eye</strong></td>
<td><strong>Ganglion cell type</strong></td>
<td><strong>LGN cell type</strong></td>
</tr>
<tr>
<td>Contralateral</td>
<td>P-type</td>
<td>Parvocellular</td>
</tr>
<tr>
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Figure 10.10: A summary of ganglion cell inputs to the different LGN layers. There is a thin koniocellular layer (shown in pink) ventral to each of the six principal layers.
Visual Striate Cortex
Information Processing

- 250 million neurons
- Process the incoming information from LGN
  - Make it clearer
- Neurons are specialized to respond to *(feature detectors)*
  - Orientation
  - Spatial Frequency
  - Length
  - Corners
  - Motion
Three types of Cells

- Simple Cells
- Complex Cells
- End Stopped Cells
Simple Cells

- Orientation sensitive
- Cylindrical shape excitatory center and inhibitory surround
  - Edge detectors
- Four different kinds
Four kinds of Edge Detectors

A. Light Line Detector

B. Dark Line Detector

Firing Rate

Horizontal Position
Four kinds of Edge Detectors

C. Dark-to-light Edge Detector

D. Light-to-dark Edge Detector

Firing Rate

Horizontal Position
May have complex receptive field

- Secondary lobes
- Adjacent to primary lobes
Selective Adaptation

- When we view a certain state of a property
  - Initial phase: Neurons sensitive to it have increased firing
  - Later phase: This firing reduces and we become insensitive to this property

- *Adapt selectively* towards one particular state
Example Experiment: Orientation

- Measure sensitivity to all different orientation
- Adapt to one orientation
- Measure sensitivity to all different orientation again
- Find the change in the sensitivity
Selective Adaptation

If stimulated by the same stimulus for a long time, sensitivity to the stimulus decreases.
Designing the Experiment

- **Stimulus**
  - Grating Pattern

- **Sensitivity Measure**
  - Contrast threshold

- **Contrast**
  - Define as the amplitude/mean of grating
  - Threshold: amount of contrast required to detect grating
  - Sensitivity: 1/threshold
Complex Cells

- Orientation Sensitive
- Non-linear
  - Never respond to stationary spot
  - Difficult to find their receptive field

- Motion Sensitivity
  - Responds to moving lines
  - Often, depends on the direction of motion
Complex Cells

- **Position Insensitivity**
  - Does not matter if the position of the stimulus changes slightly

- **Spatial Extension**
  - Larger receptive fields than the simple cells
End Stopped Cells

- Far more specific
- Respond to moving lines and corners
  - Of specific length
  - Of specific orientation
  - Of specific size
- Probably hypercomplex version of the simple and complex cells
What this shows...

- Our eye is very sensitive to edges, corners
- Any kind of features
Organization

- Retinotopic Map
- Cortical Magnification
  - Fovea is 0.01% of retina
  - Retinotopic map of fovea is 8-10% of cortex
Cortical Magnification

- Density of receptors and ganglion in retina is very mismatched
  - In fovea about 50,000 ganglion cells per sq. mm.
  - In periphery about 1000 ganglion cell per sq. mm.
- Density of neurons from fovea and periphery is close to uniform
Cortical Magnification

- Foveal input allocated extra cortical neurons
- Three to six times more than those at periphery
- One of the factors for higher acuity in the fovea
Location Columns

- Retinotopic Map
- Same region on retina along the depth
- Adjacent regions in the retina correspond to adjacent columns
Orientation Columns

- Orientation column perpendicular to retinotopic columns
- Same columns have similar orientation preference
- Orientation preference changed across columns continually
- For every 1mm region, the entire range of orientations were covered
Ocular dominance columns

- Each columnar region is more sensitive to one eye
- The dominant eye alternates between the columnar regions
Hypercolumn View of the Cortex
Information Processing by Cortex
Development of Receptive Fields

- Is it there from birth?
- How much is the development dependent on learning?
- Experiments with visually deprived kittens
EDGE DETECTION
Edge Detectors

First-Order Edge Operators

A. Vertical

B. Horizontal

Second-Order Edge Operators

C. Vertical

D. Horizontal

E. Omnidirectional
Convolution & Feature Detection

A. Grayscale Image

B. Image Intensities

C. Vertical Edge Operator

D. Horizontal Edge Operator

E. Convolution of Image with Vertical Edge Operator

F. Convolution of Image with Horizontal Edge Operator
Edge Detectors

- Finds the slope
  - First derivative
  - Direction dependent
  - Need many edge detectors for all orientation

- Second order derivatives
  - Marr Hildreth Method
Zero Crossing Curvature

- Maxima of derivative
  - Causes a zero at second derivative
- Symmetric about the zero
- All direction edges can be detected by this zero crossing
Similarity with Receptive Fields
Results of the Algorithm

A. The image
B. Image after convolution
C. Segmented convolved image
D. Edge detected image
Neural Model

- Three cells
  - Convolution
  - Maxima detection
  - Zero detectors
  - Aligned zero detectors to form edge detectors
Neural Model

- Three cells
  - Convolution
    - Lateral Inhibition
  - Maxima detection
    - Simple Cortical Cells
  - Zero detectors
    - Complex Cortical Cells
  - Aligned zero detectors to form edge detectors
Scaling Problem

- Can occur in different scales or sizes
  - Some have the transition over a broader region
  - Some over a smaller region
  - Edges nevertheless and has to be detected

- Edge detection are done at several levels
  - Image is sub sampled
    - Reduces information content
  - Then edge is detected
Scaling Problem
Scaling Problem

- Edges in coarser level do not disappear in finer levels
- New edges are added
- Coarser level edges are most important
- Advances like a hierarchy
Scale Integration

- Different resolution images in different levels
- How do we know where the coarser level edges are in the finer edge detected image
- Seems very complex yet eye does it easily
Witkin’s Explanation

- If we do a continuous subsampling
  - Not possible in digital domain
- Edges are retained, new edges are added with refinement
HIGHER-LEVEL VISUAL PROCESSING
Extrastriate Cortex

- Hubel and Weisbl won Noble prize for their discovery of the cortical cells
- By 1970s, found that other regions of the brain are also involved in vision.
- Cells that respond to far more complex stimuli
Contextual Modulation

- Stimulation can be changed by changing their context
- Salience: Degree to which things stand out
Physiological Explanation

- Notice 80ms initial quiet
  - Time required to process salience
- Adverse effect on selective adaptation
Processing Streams

- Dorsal Pathway
  - Parietal Lobe
  - ‘Where’
  - Location and Action

- Ventral Pathway
  - Temporal Lobe
  - ‘What’
  - Object Discrimination
Supporting Experiments

(a) Object discrimination

(b) Landmark discrimination

Area removed
The Whole Pathway

- Parallel Path
- Not independent
- P-cells to ventral
- M-cells to parietal
Modular Neurons

- Neurons in MT and IT
- Process very specific information
- Experiment of motion correlation
Experiment with motion correlation

- If MT present, can detect as small as 1-2% correlation
- If MT absent, cannot detect less than 10-20% correlation
Infotemporal cortex

- **Primary Cells**
  - Respond to simple stimuli
    - Slits, spots, ellipses, squares

- **Elaborate Cells**
  - Responds to complex stimuli
    - Specific shapes, shapes with color and texture
Hypercolumn Again
Neurons respond to faces

- If a body with face is presented as stimuli, they fire
- When the face is covered with paper, they stop firing
- fMRI research with humans
  - Fusiform face area (FFA) or fusiform gyrus
- Prosopagnosia
  - Due to damage to temporal lobe
  - Fusiform gyrus
The Sensory Code

- Information encoded in the firing of neurons
  - Specificity Coding
    - Every neuron responds to a specific stimuli
  - Distributed Coding
    - Difference in amounts of response in several different neuron creates a pattern that causes identification of specific stimulus
    - To some extend, like number system
    - More number of levels for each neuron, lesser the number of neurons needed for coding
The Sensory Code

- Information encoded in the firing of neurons
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Neurons in IT for Face Recognition

- Size invariant
- Location invariant
- View invariant
- Size specific
- Location specific
- View specific
Role of Attention

- Selectivity of attention
  - Directs our receptors to stimuli
  - Enhances the perception of stimuli
Inattentional Blindness

- Cannot recognize shape of unattended object when attending to some other visual job
- Experiments of shape presented while performing the task of identifying shorter length
- https://www.youtube.com/watch?v=vJG698U2Mvo
Attentional Blink

- Inability to attend to a different stimulus within a short period of 500ms
- Demonstrated by rapid serial visual presentation (RSVP)
Change Blindness

- Inability to detect unattended changes
- Even when the stimulus is presented slowly
Examples

- https://www.youtube.com/watch?v=uO8wpm9HSB0
- https://www.youtube.com/watch?v=bh_9XFZbWV8
- https://www.youtube.com/watch?v=FWSxSSspiQ
Binding Problem

- How do we know it is all from the same object
  - Example of a car
- Depends on the synchrony of neuron firing
- If same object, all the different neurons fire synchronously
- Cross correlogram plots of the brain
Cross Coreleograms