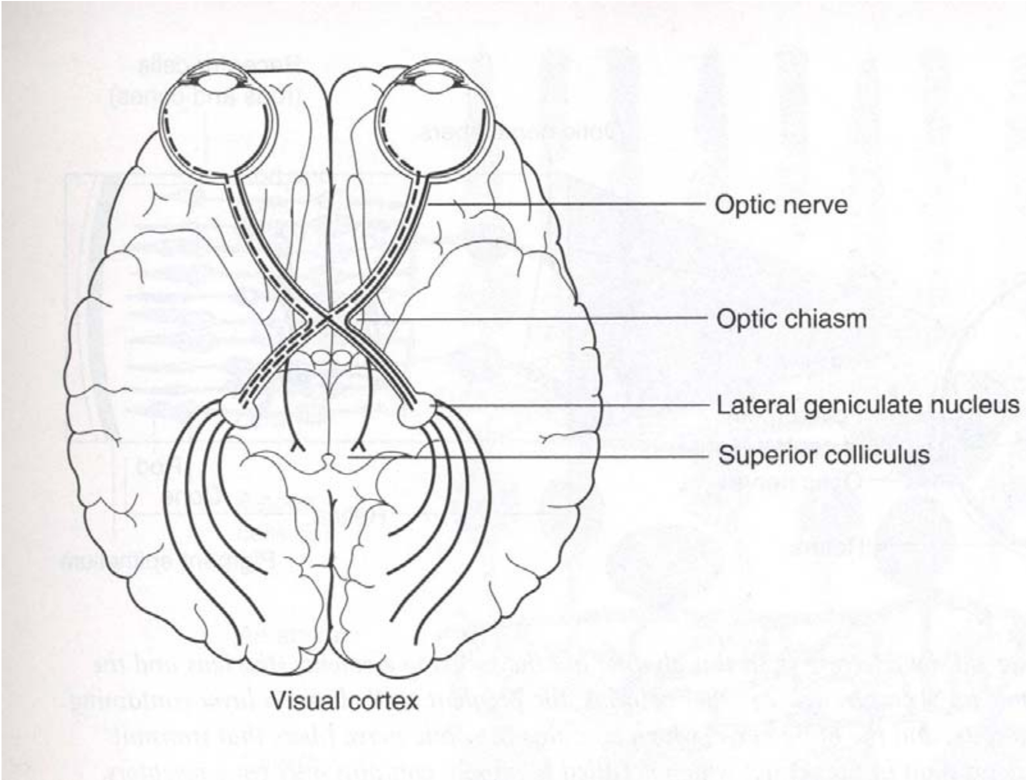
Lateral Geniculate Nucleus (LGN)

What happens beyond the retina?

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



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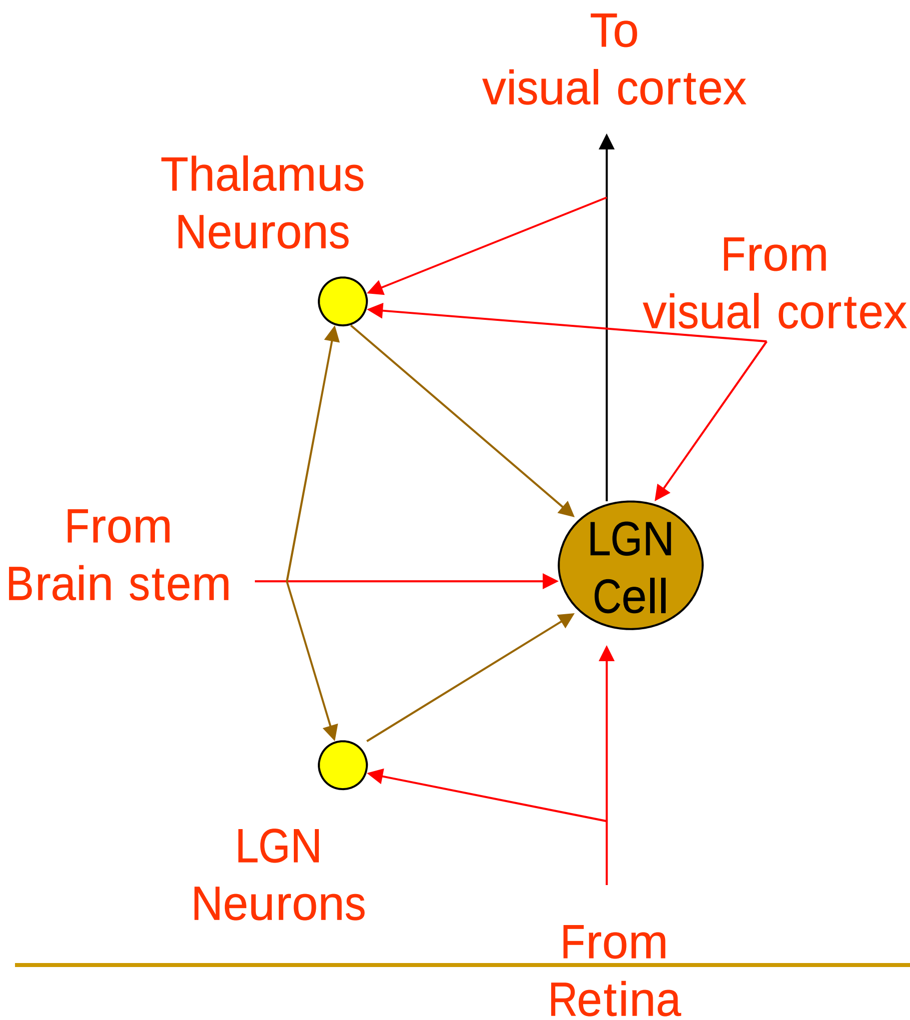
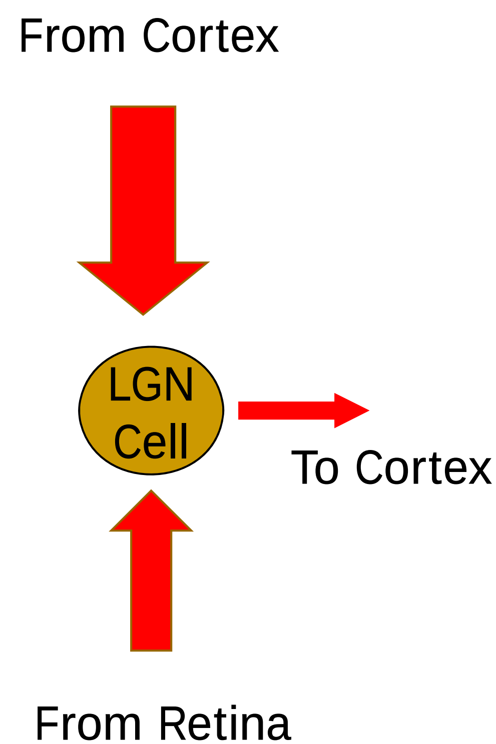
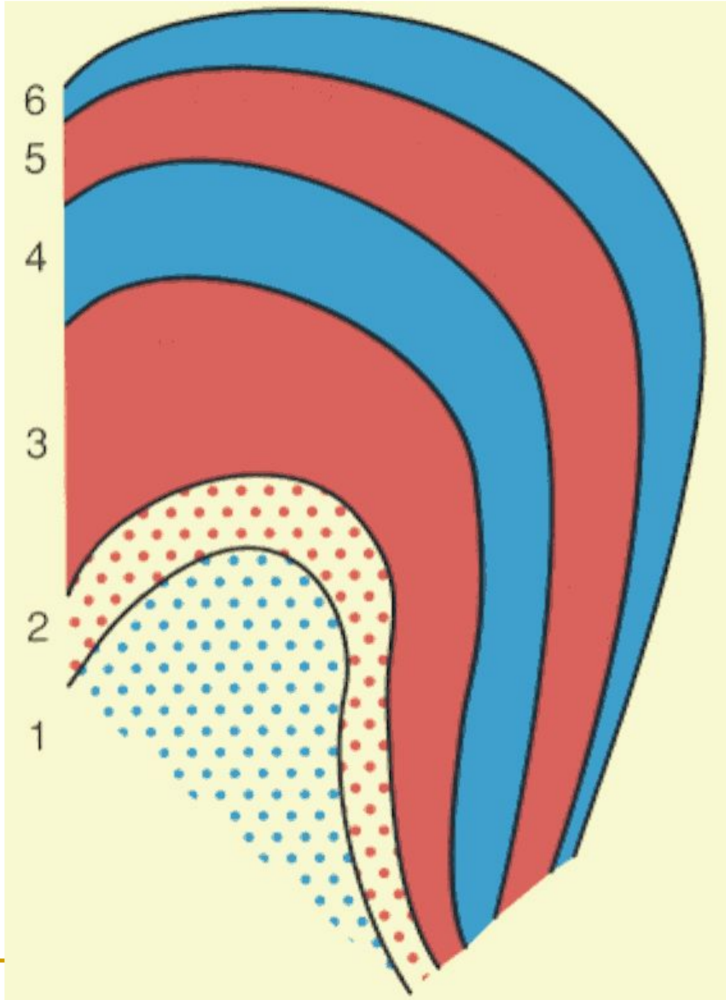
Information flow in LGN





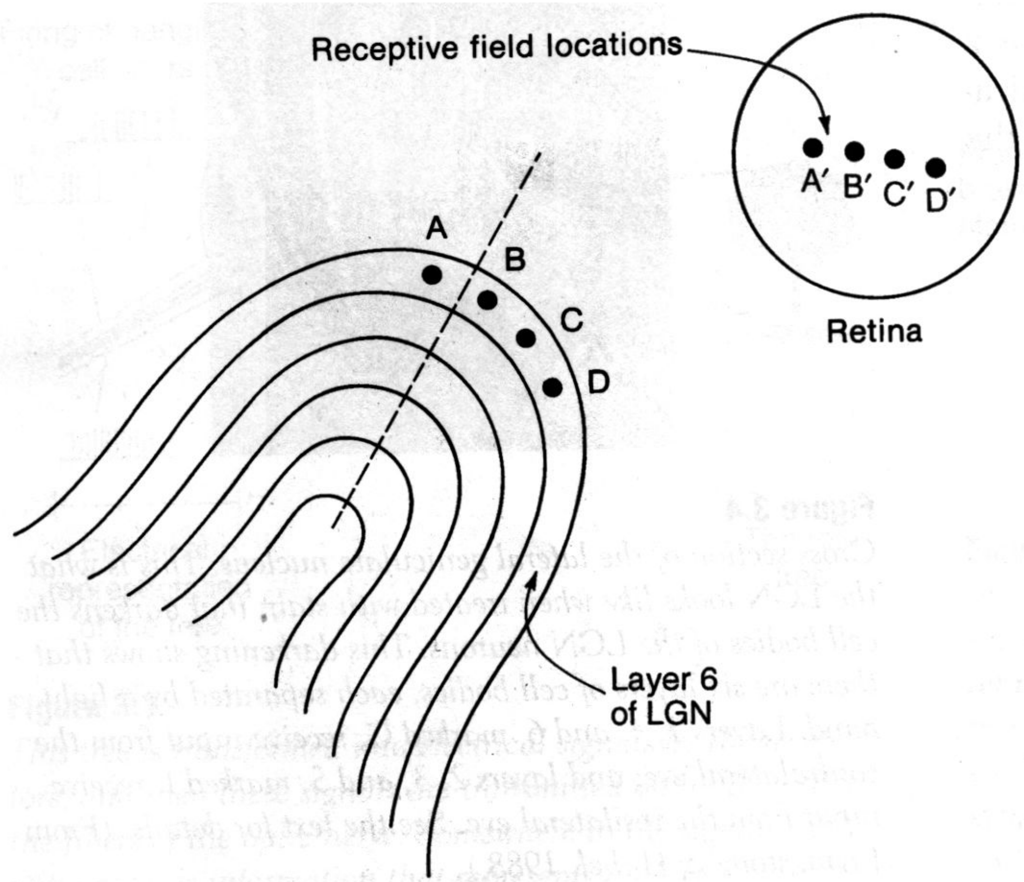
Information Organization in LGN

- 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



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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

Retinal output: Eye	Retinal output: Ganglion cell type	LGN: LGN cell type	LGN: Layer
Contralateral	P-type →	Parvocellular	6
	nonM-nonP →	Koniocellular	
Ipsilateral	P-type →	Parvocellular	5
	nonM-nonP →	Koniocellular	
Contralateral	P-type →	Parvocellular	4
	nonM-nonP →	Koniocellular	
Ipsilateral	P-type →	Parvocellular	3
	nonM-nonP →	Koniocellular	
Ipsilateral	M-type →	Magnocellular	2
	nonM-nonP →	Koniocellular	
Contralateral	M-type →	Magnocellular	1
	nonM-nonP →	Koniocellular	

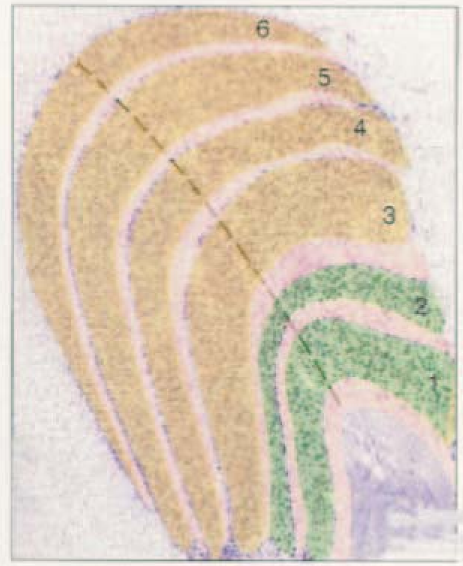


Figure 10.10
A summary of ganglion cell inputs to the different LGN layers. There is a thin koniocellular layer (shown in pink) ventral to each of the six principal layers.

Visual Striate Cortex

Information Processing

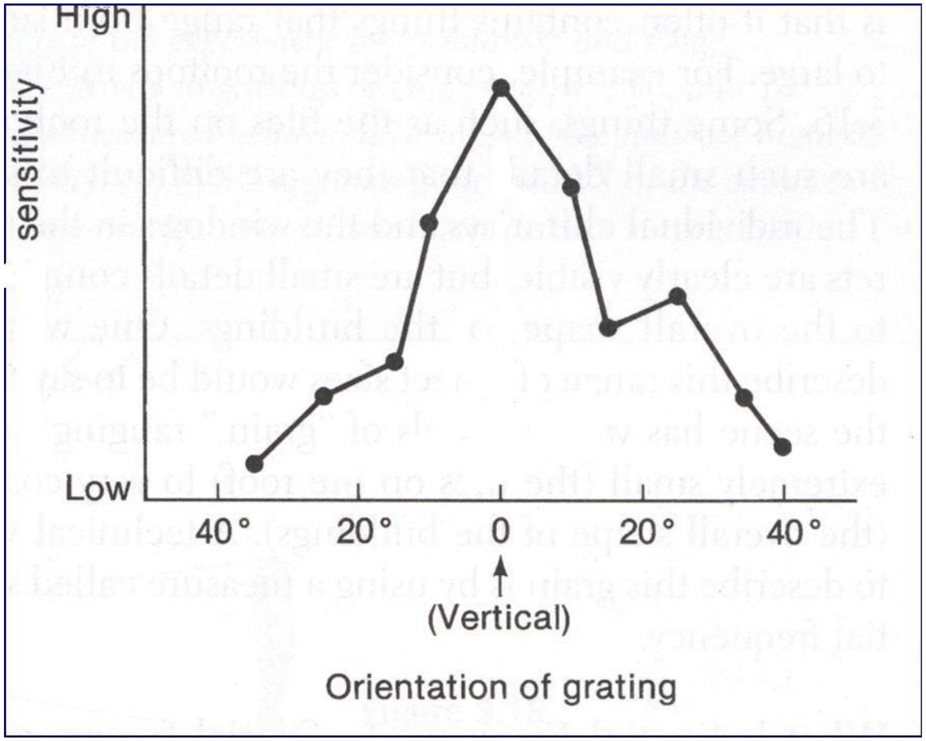
- 250 million neurons
- Process the incoming information from LGN
  - Make it clearer
- Neurons are specialized to respond to (*feature detectors)*
  - Orientation
  - Spatial Frequency
  - Length
  - Corners
  - Motion

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



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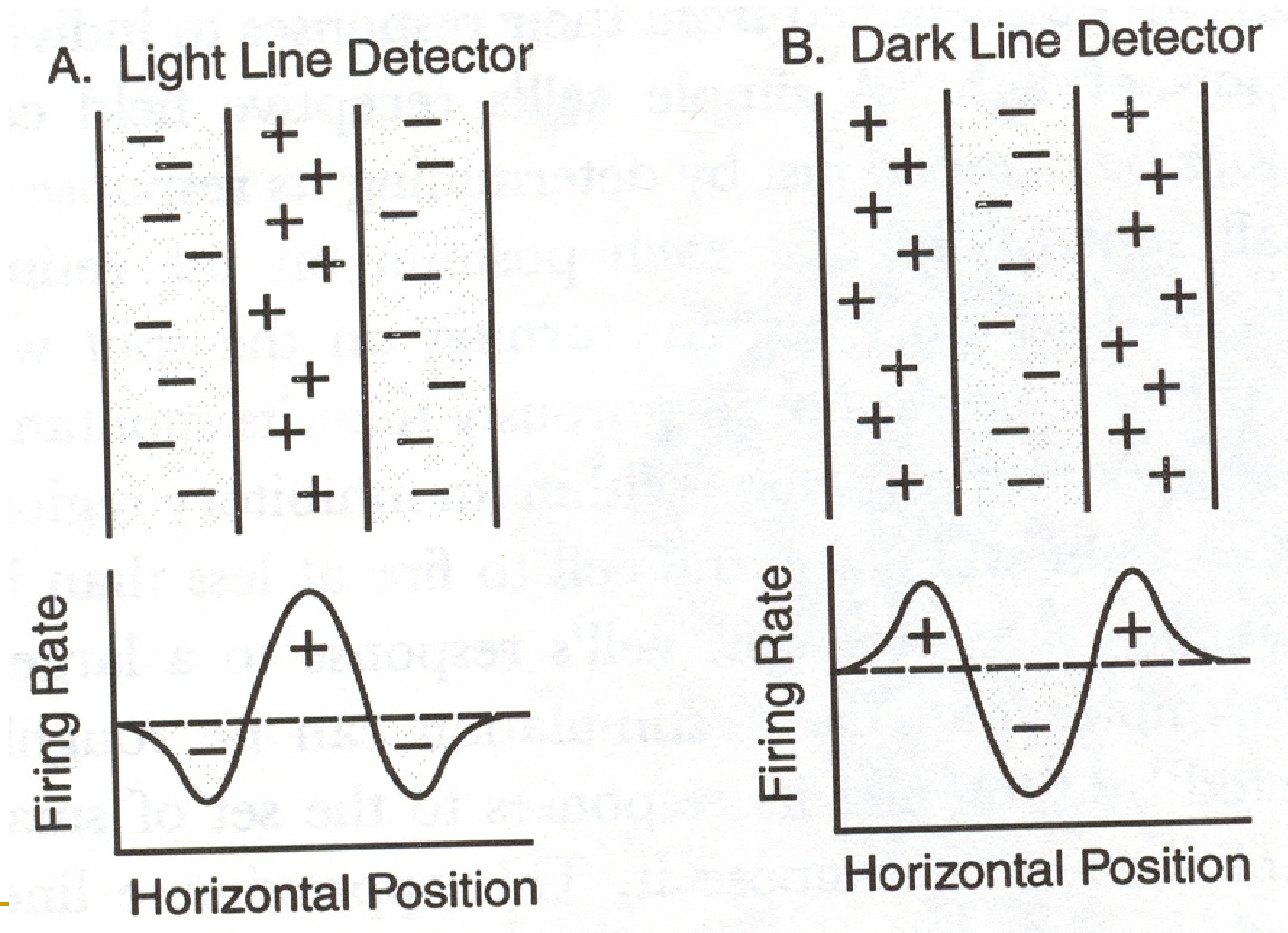
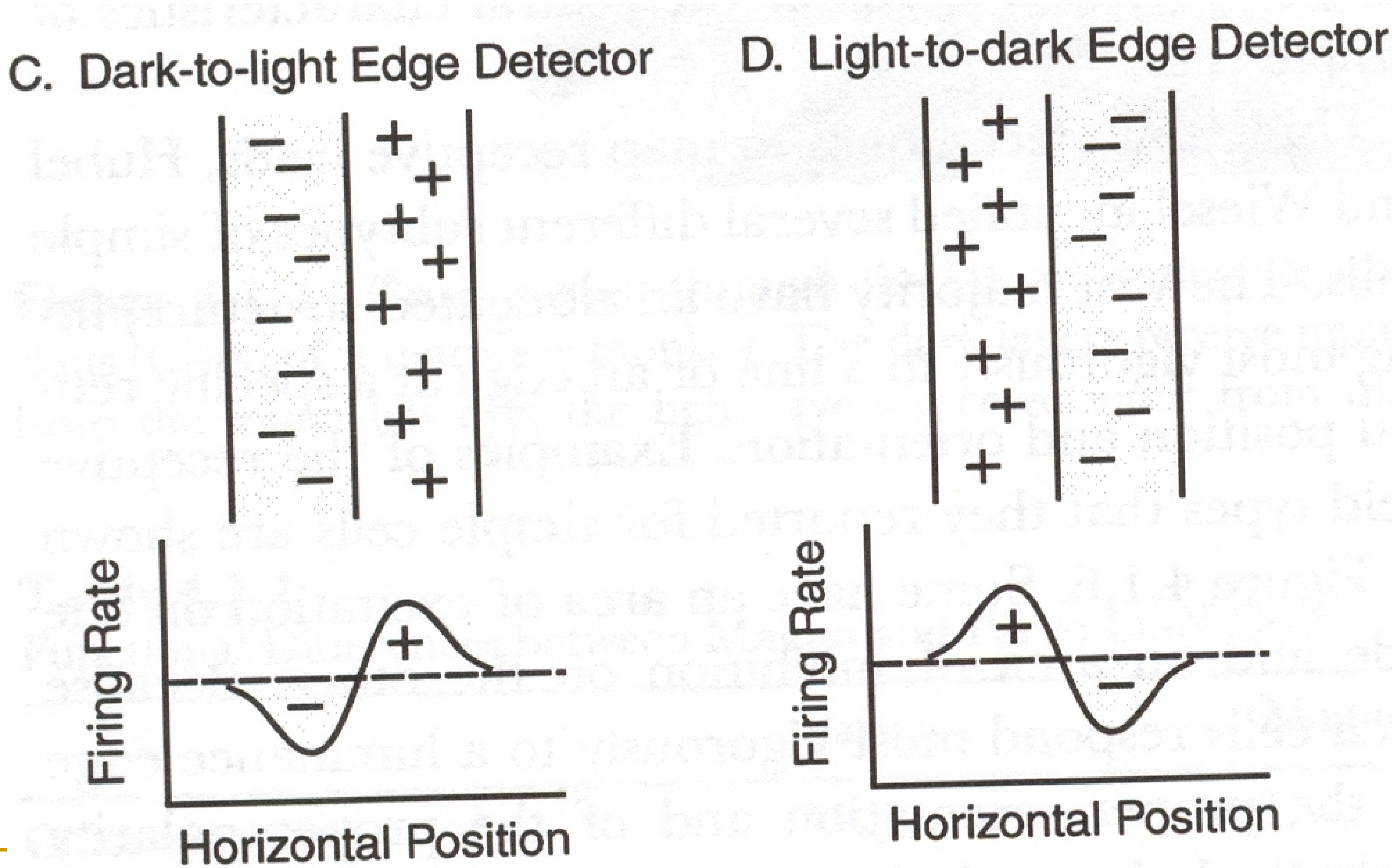
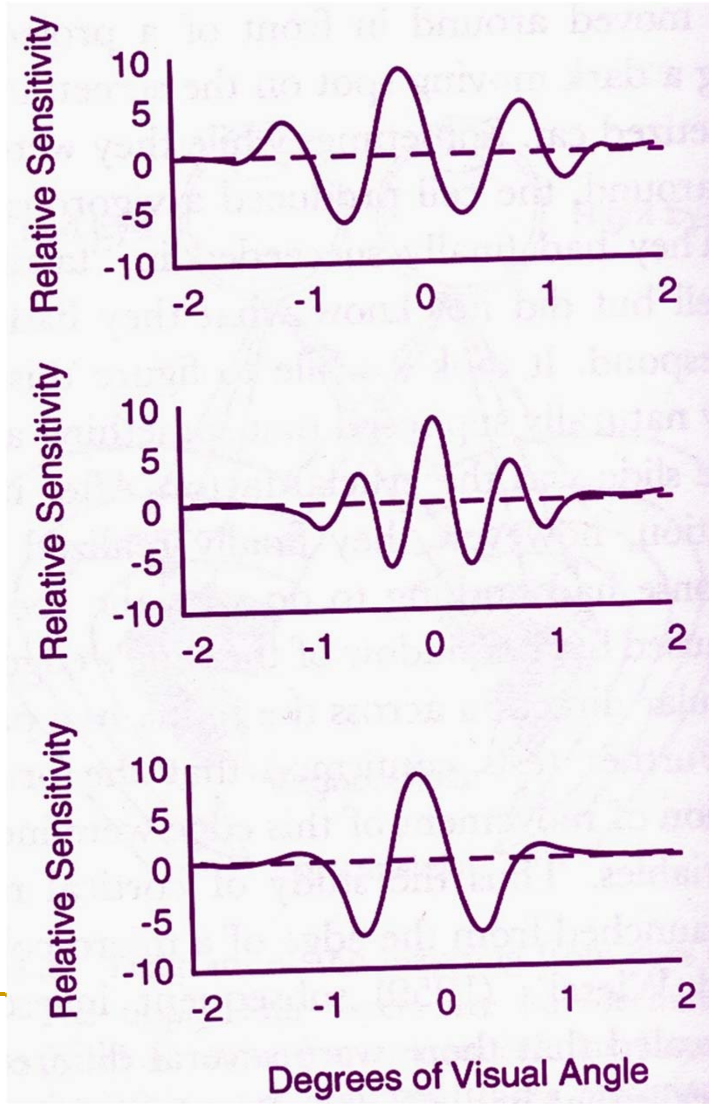
Four kinds of Edge Detectors



Four kinds of Edge Detectors



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

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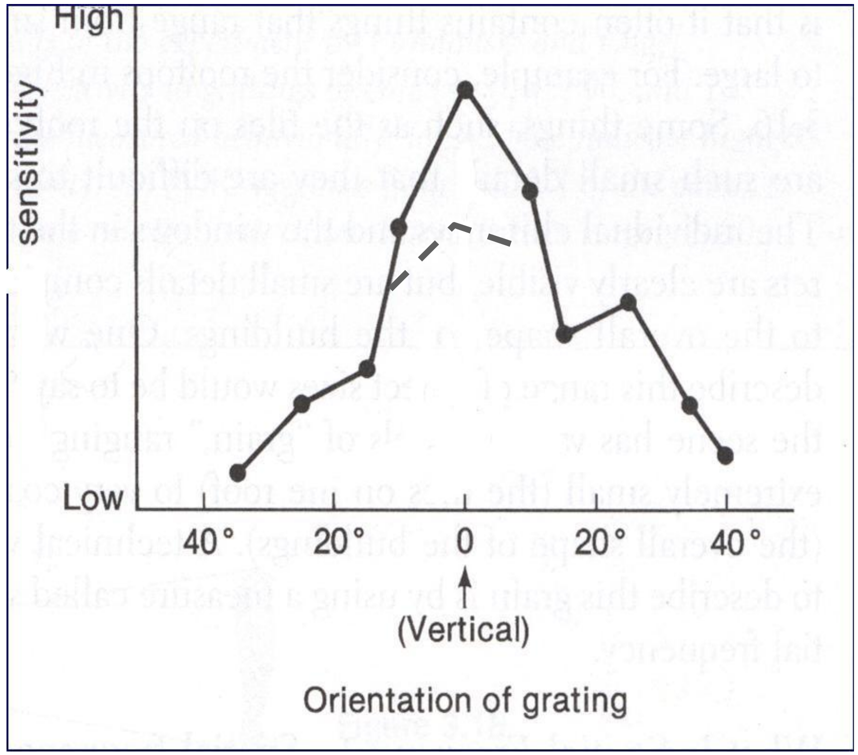
Example Experiment : Orientation

- 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 is the position of 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

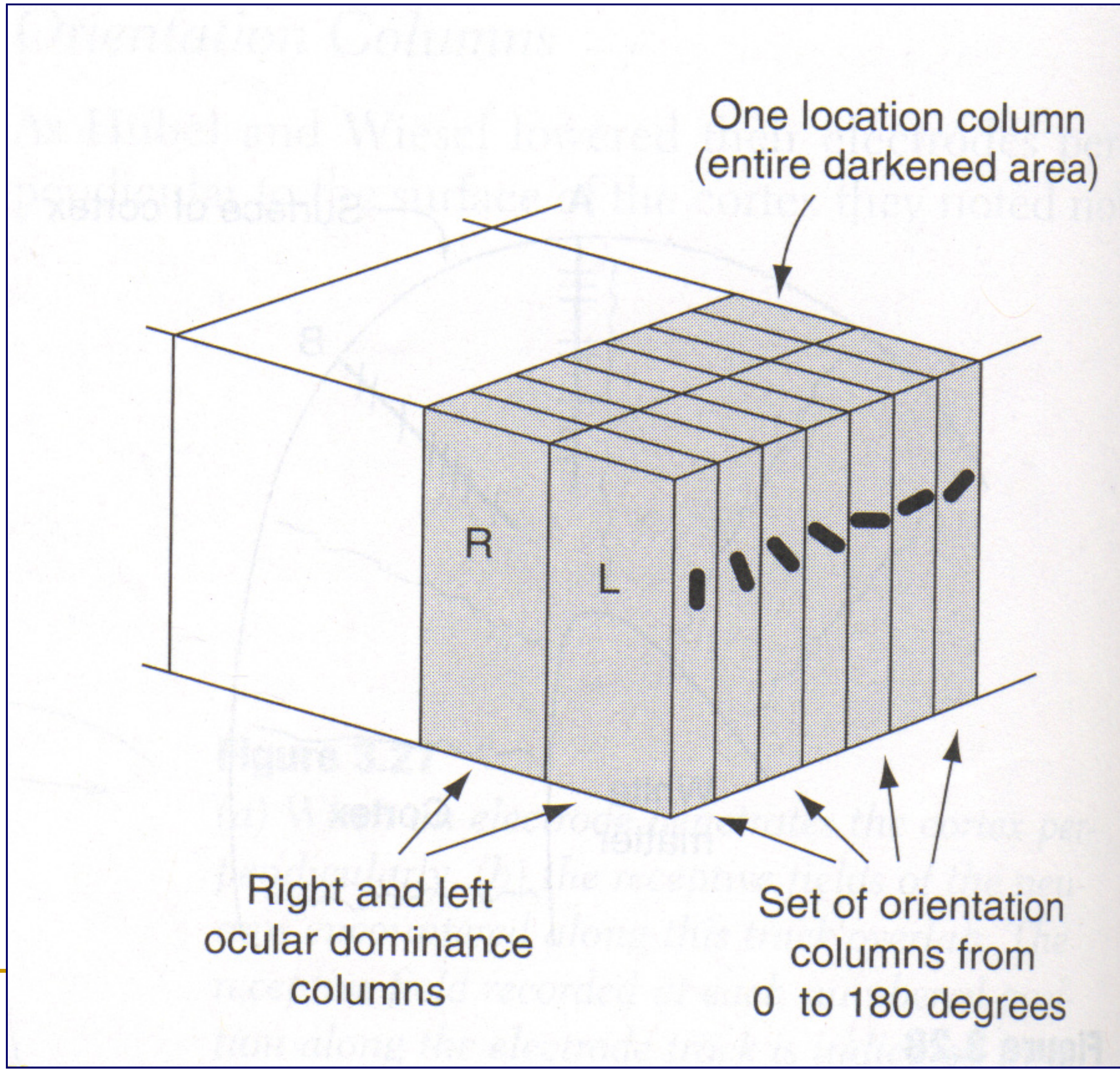
Orientation Columns

- 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

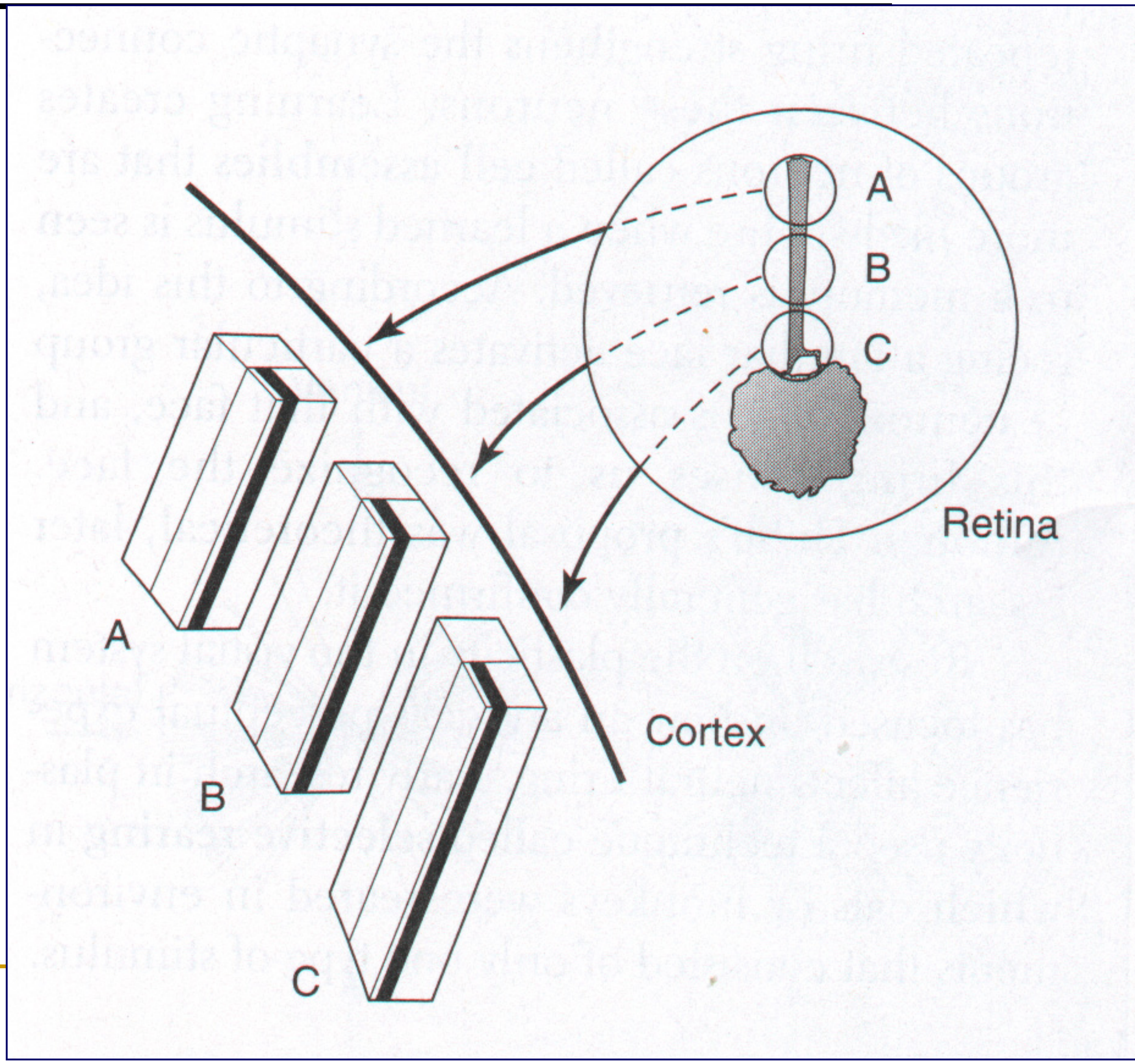
Ocular dominance columns

- 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

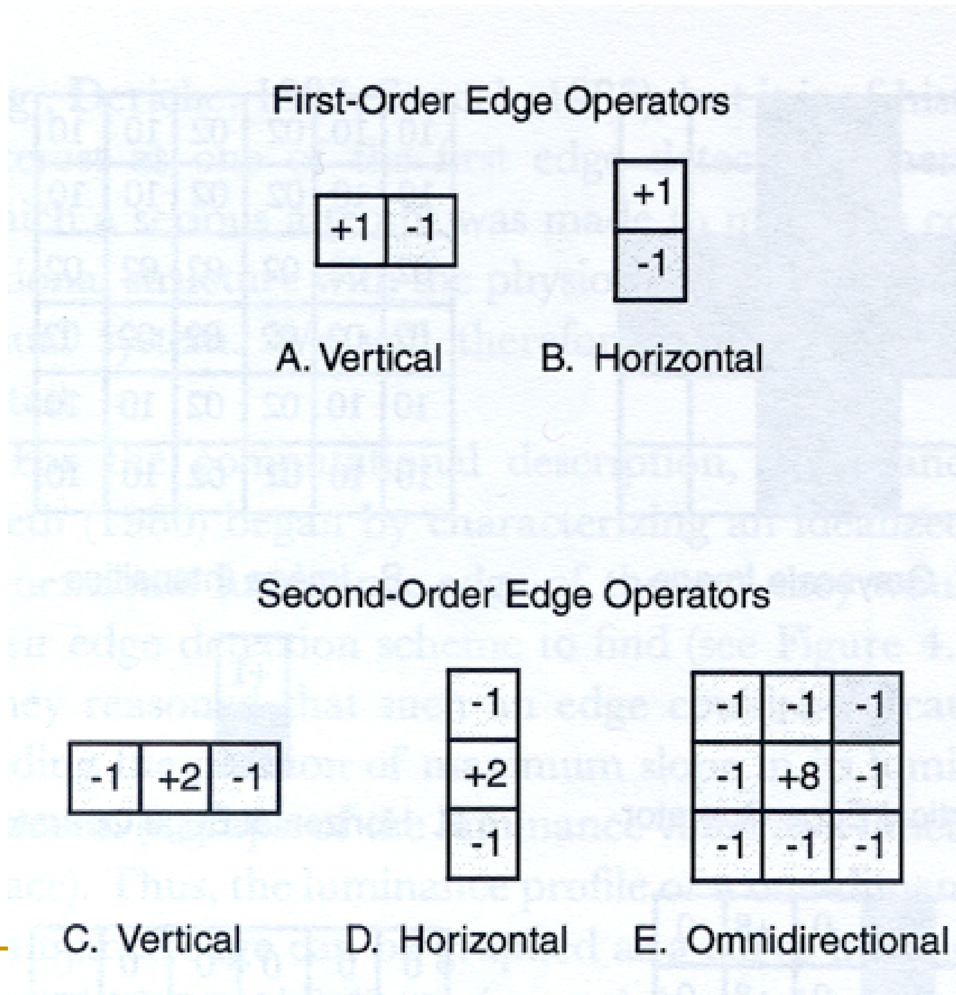


Development of Receptive Fields

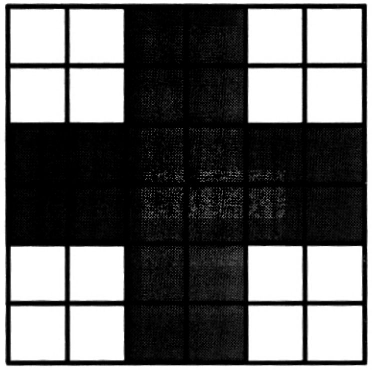
- Is it there from birth?
- How much is the development dependent on learning?
- Experiments with visually deprived kittens

EDGE DETECTION

Edge Detectors



Convolution & Feature Detection



A. Grayscale Image

10	10	02	02	10	10
10	10	02	02	10	10
02	02	02	02	02	02
02	02	02	02	02	02
10	10	02	02	10	10
10	10	02	02	10	10

B. Image Intensities

-1	+1

C. Vertical Edge Operator

+1
-1

D. Horizontal Edge Operator

0	-8	0	+8	0
0	-8	0	+8	0
0	0	0	0	0
0	0	0	0	0
0	-8	0	+8	0
0	-8	0	+8	0

E. Convolution of Image with Vertical Edge Operator

0	0	0	0	0	0
+8	+8	0	0	+8	+8
0	0	0	0	0	0
-8	-8	0	0	-8	-8
0	0	0	0	0	0

F. Convolution of Image with Horizontal Edge Operator

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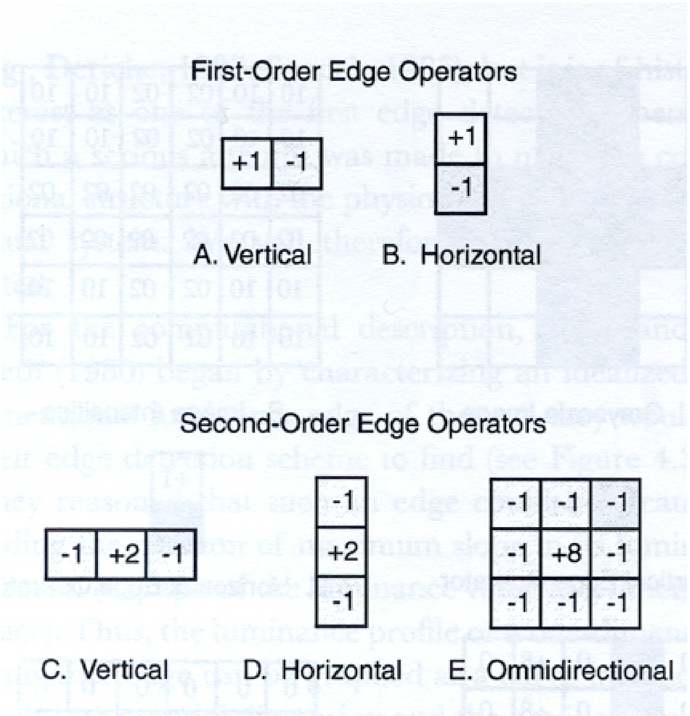
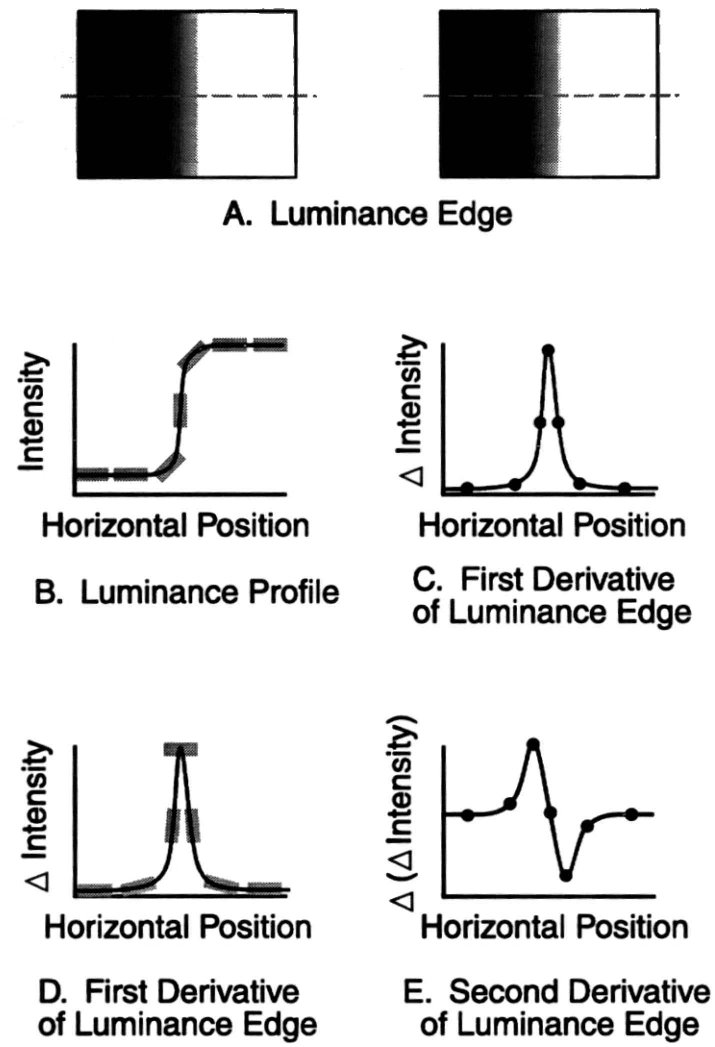
Edge Detectors

- Finds the slope
  - First derivative
  - Direction dependent
  - Need many edge detectors for all orientation
- Second order derivatives
  - Marr Hildreth Method

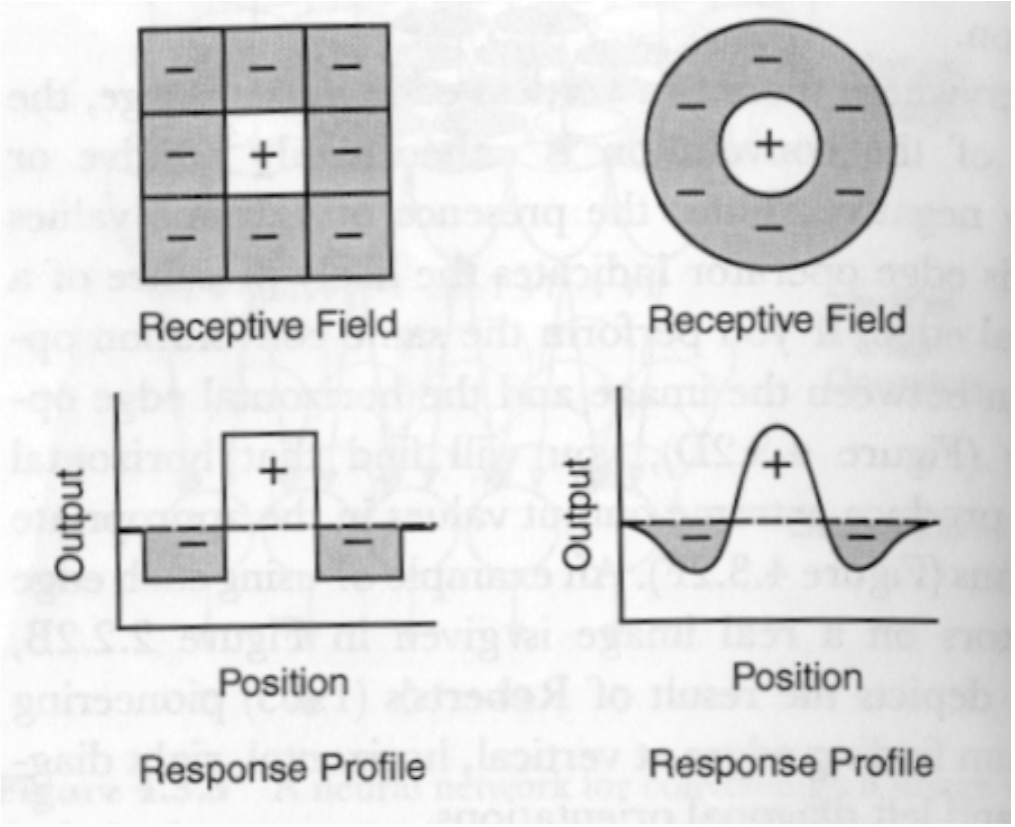


Zero Crossing Curvature

- 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



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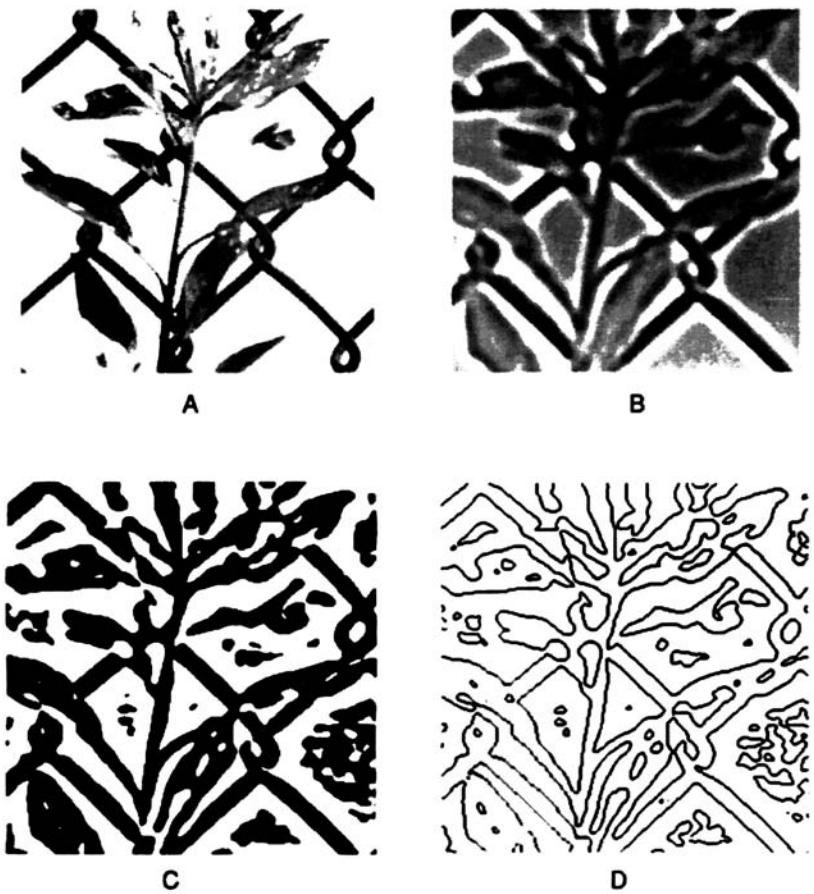
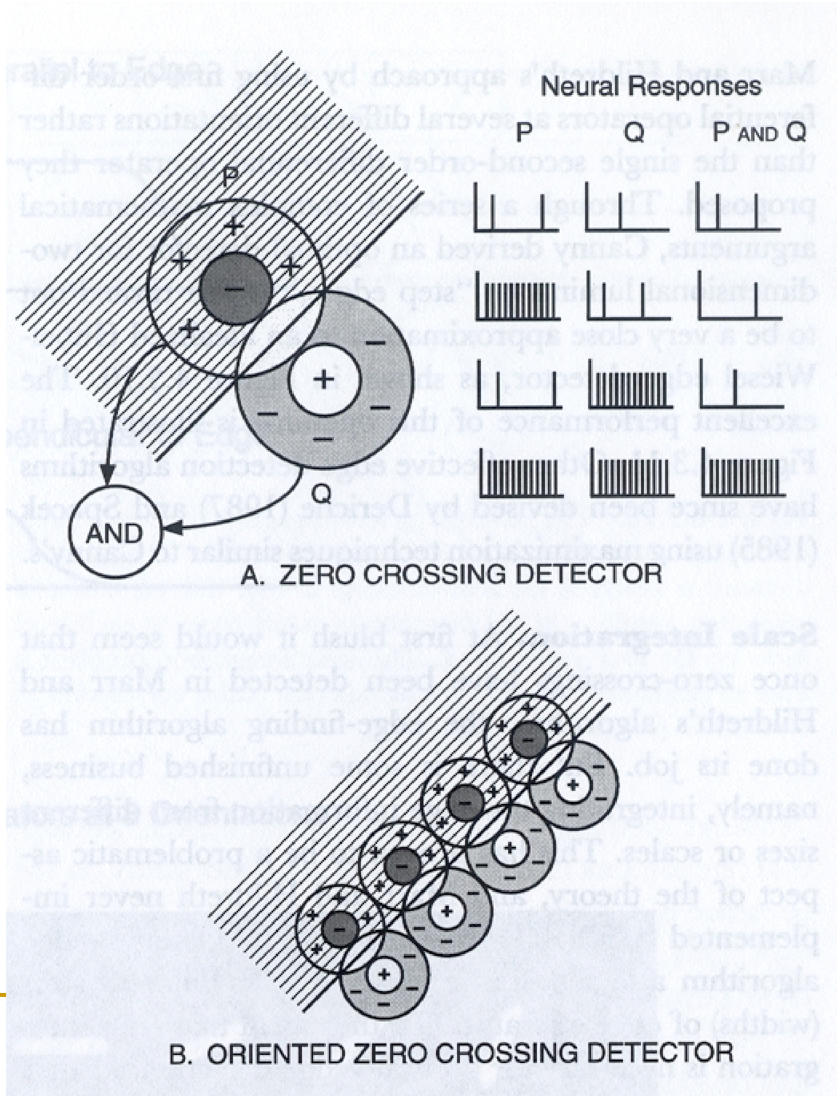
Results of the Algorithm



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

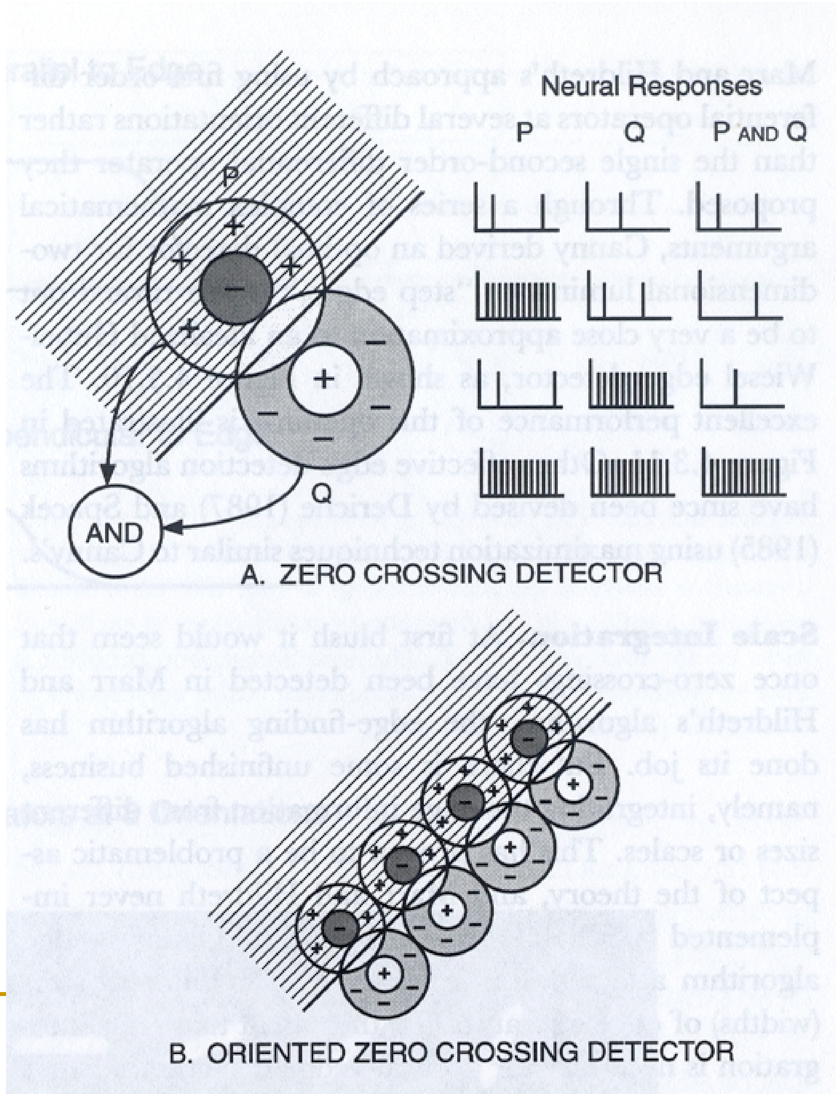
Neural Model

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



Neural Model

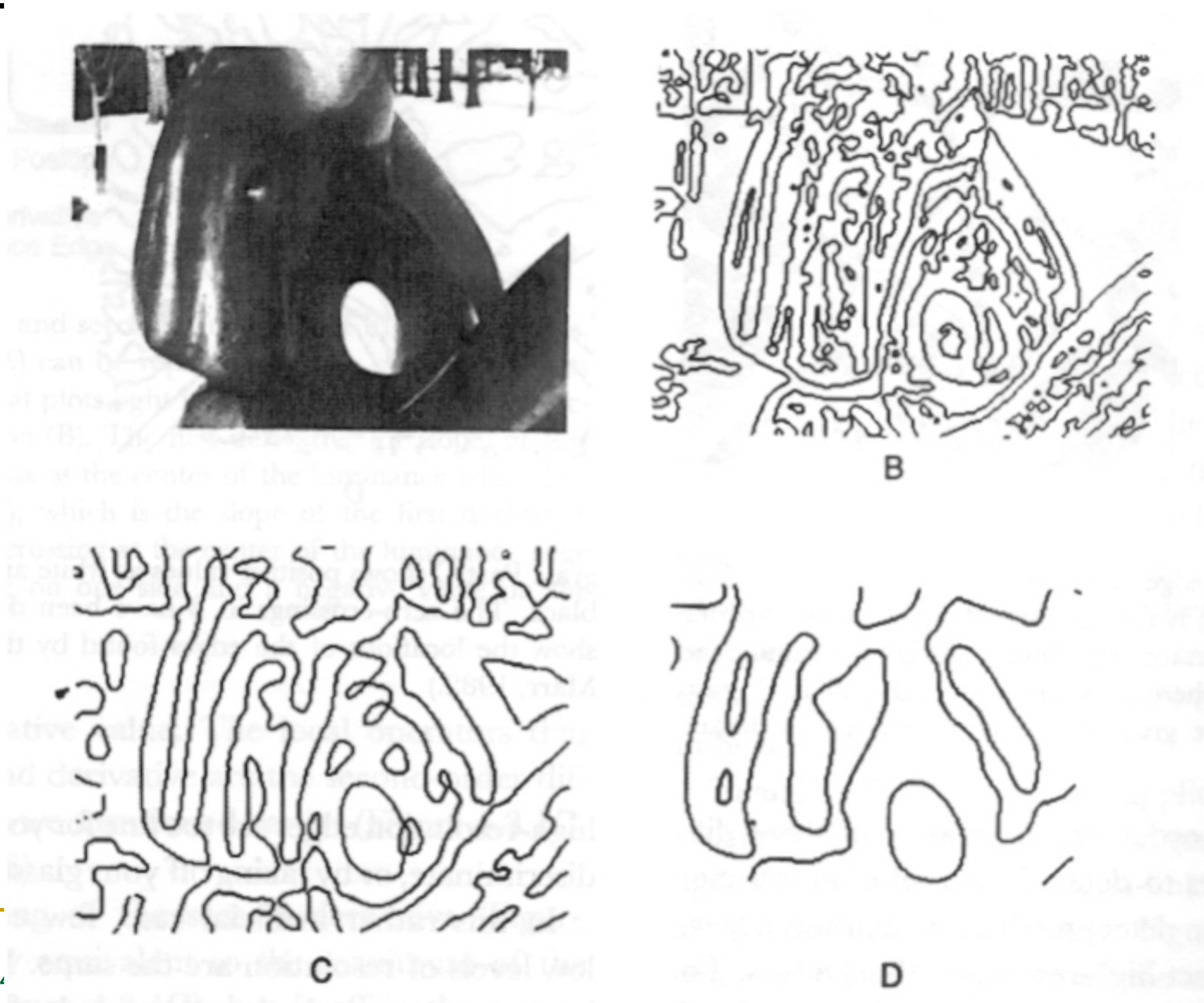
- Three cells
  - Convolution
    - Lateral Inhibition
  - Maxima detection
    - Simple Cortical Cells
  - Zero detectors
    - Complex Cortical Cells
  - Aligned zero detectors to form edge detectors



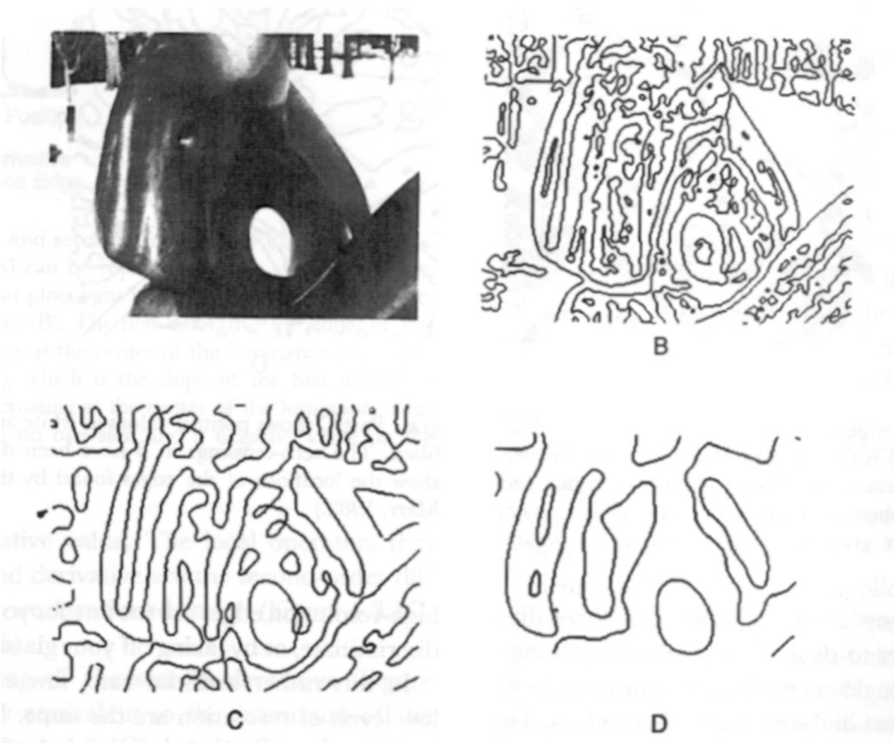
Scaling Problem

- 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



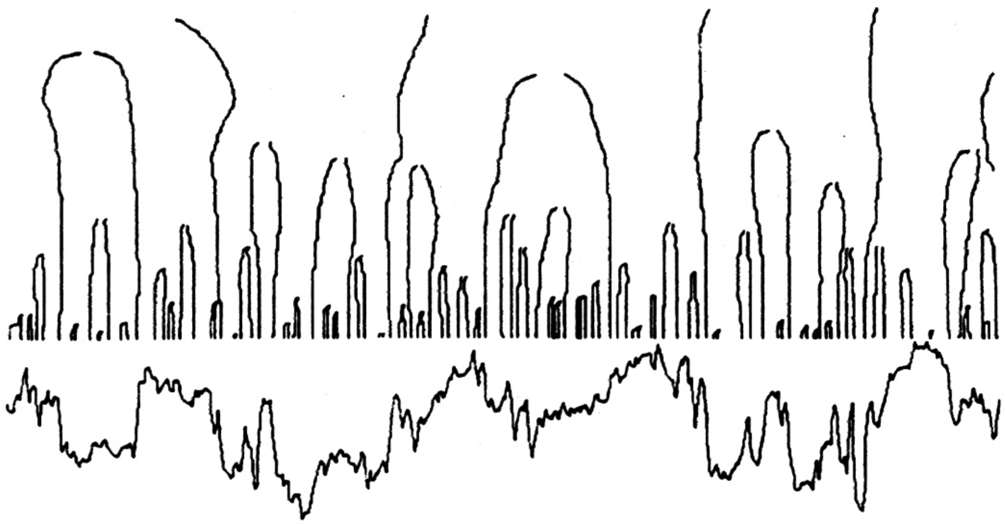
- Edges in coarser level do not disappear in finer levels
- New edges are added
- Coarser level edges are most important
- Advances like a hierarchy

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

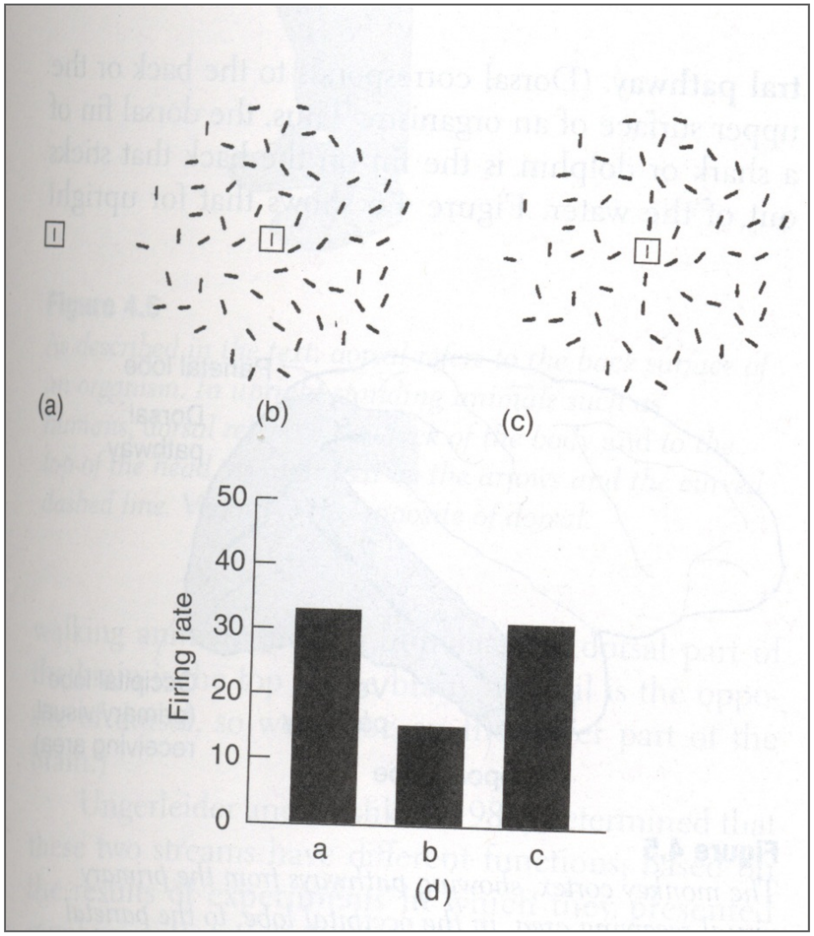


HIGHER-LEVEL VISUAL PROCESSING

Extrastriate Cortex

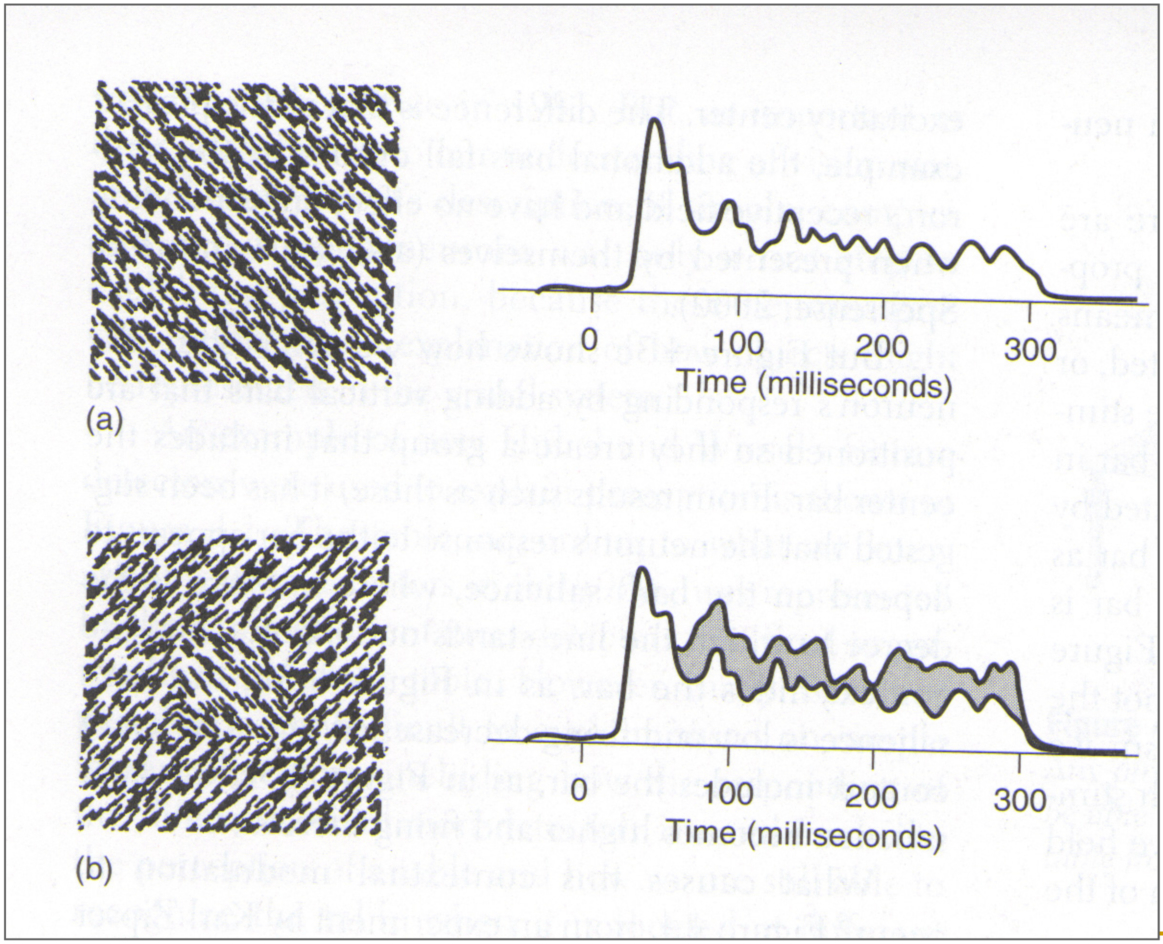
- Hubel and Weisl won Noble prize for their discovery of the cortical cells
- By 1970s, found that other regions of the brain are also involved in vision.
- Cells that respond to far more complex stimuli

Contextual Modulation



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

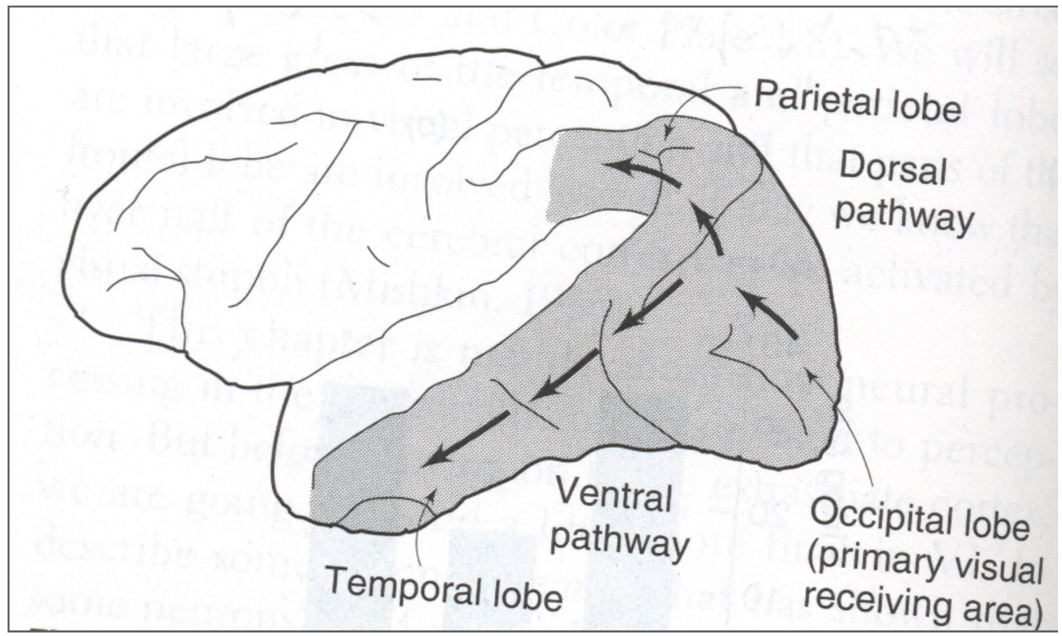
Physiological Explanation



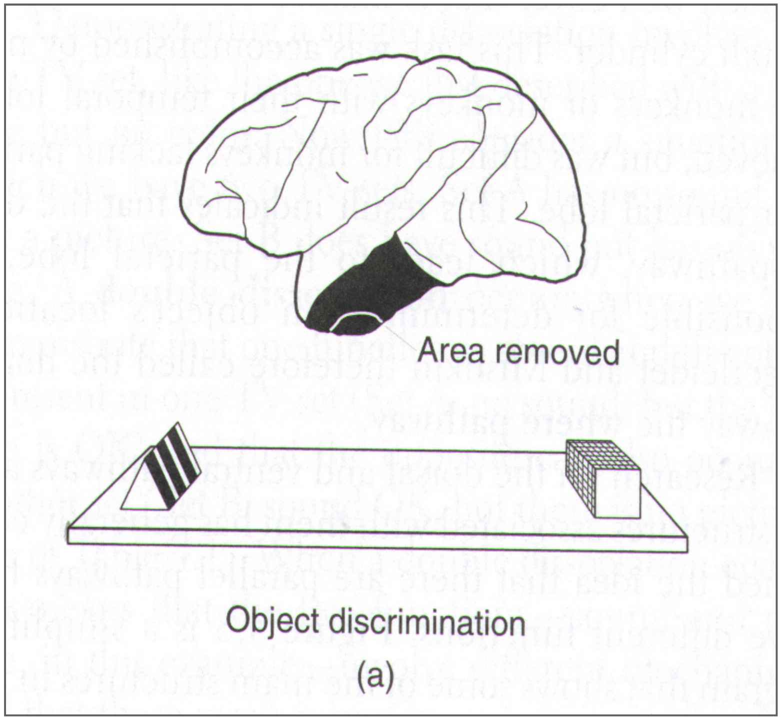
- Notice 80ms initial quiet
  - Time required to process salience
- Adverse effect on selective adaptation

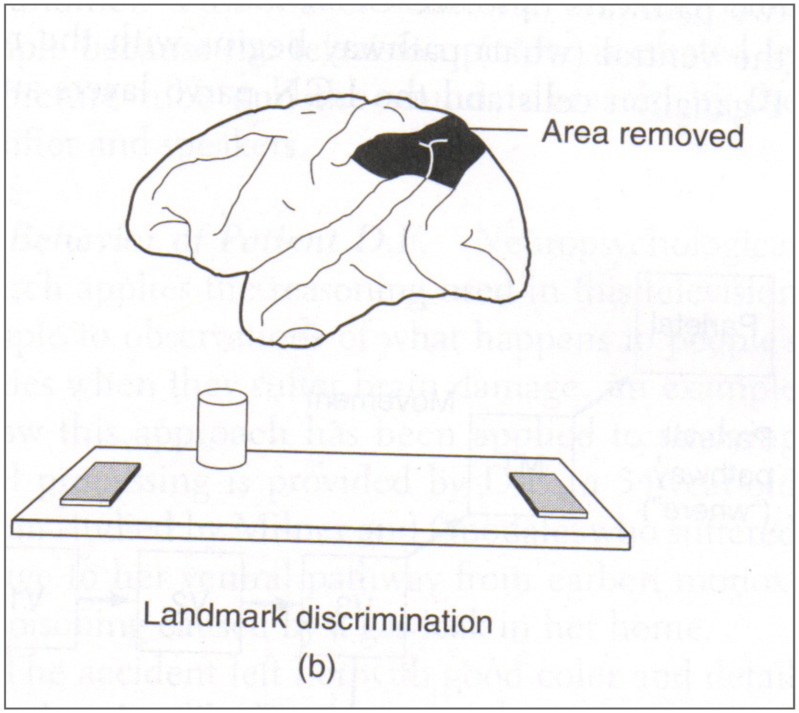
Processing Streams

- Dorsal Pathway
  - Parietal Lobe
  - ‘Where’
  - Location and Action
- Ventral Pathway
  - Temporal Lobe
  - ‘What’
  - Object Discrimination



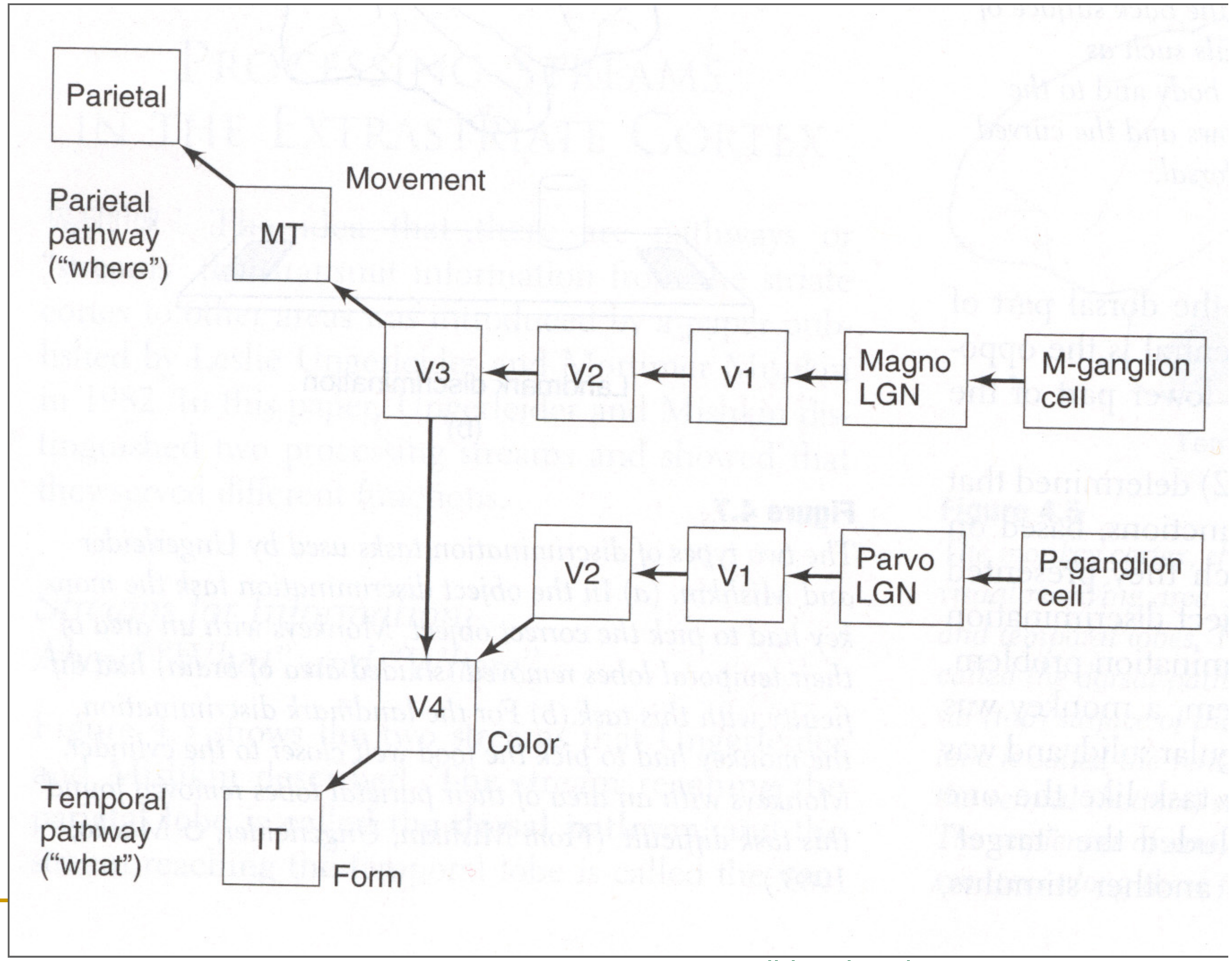
Supporting Experiments





The Whole Pathway

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



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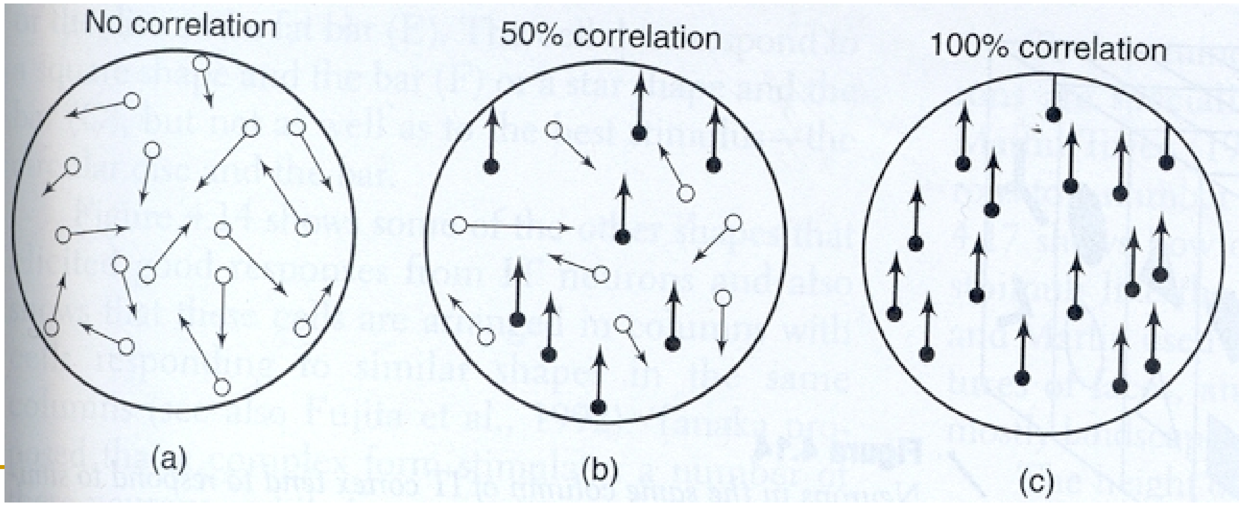
Modular Neurons

- 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

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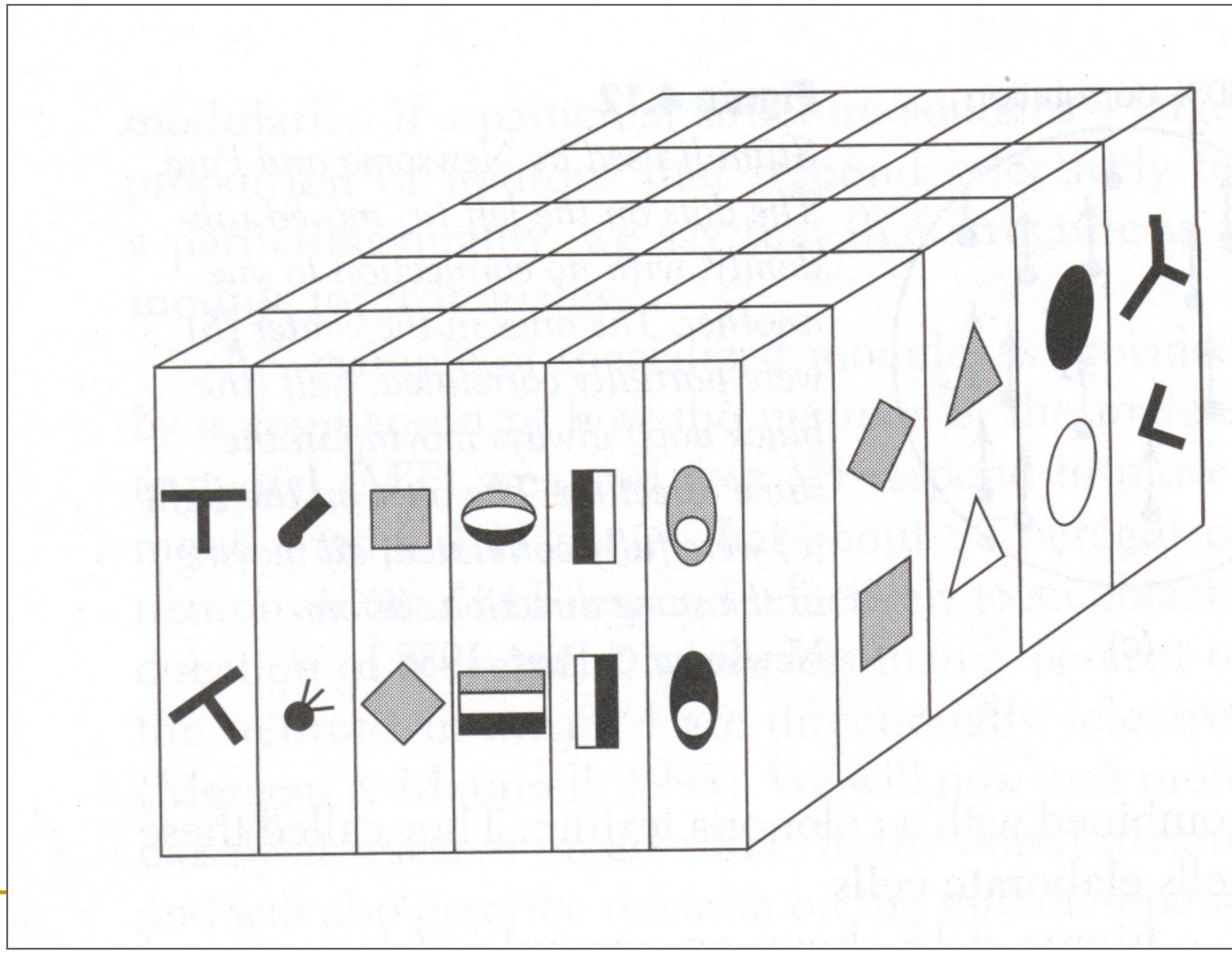
Hypercolumn Again



Neurons respond to faces

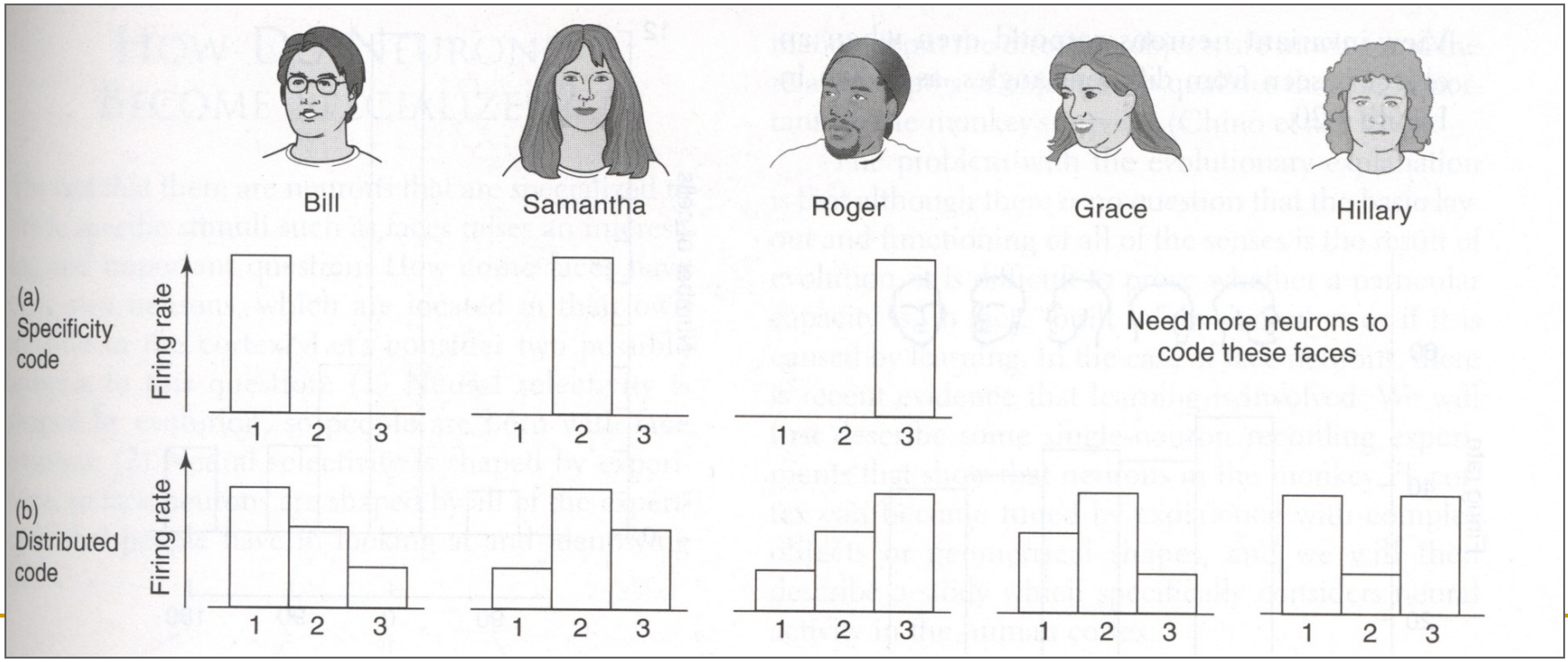
- If a body with face is presented as stimuli, they fire
- When the face is covered with paper, they stop firing
- fMRI research with humans
  - Fusiform face area (FFA) or fusiform gyrus
- Prosopagnosia
  - Due to damage to temporal lobe
  - Fusiform gyrus

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
  - Specificity Coding
  - Distributed Coding



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

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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

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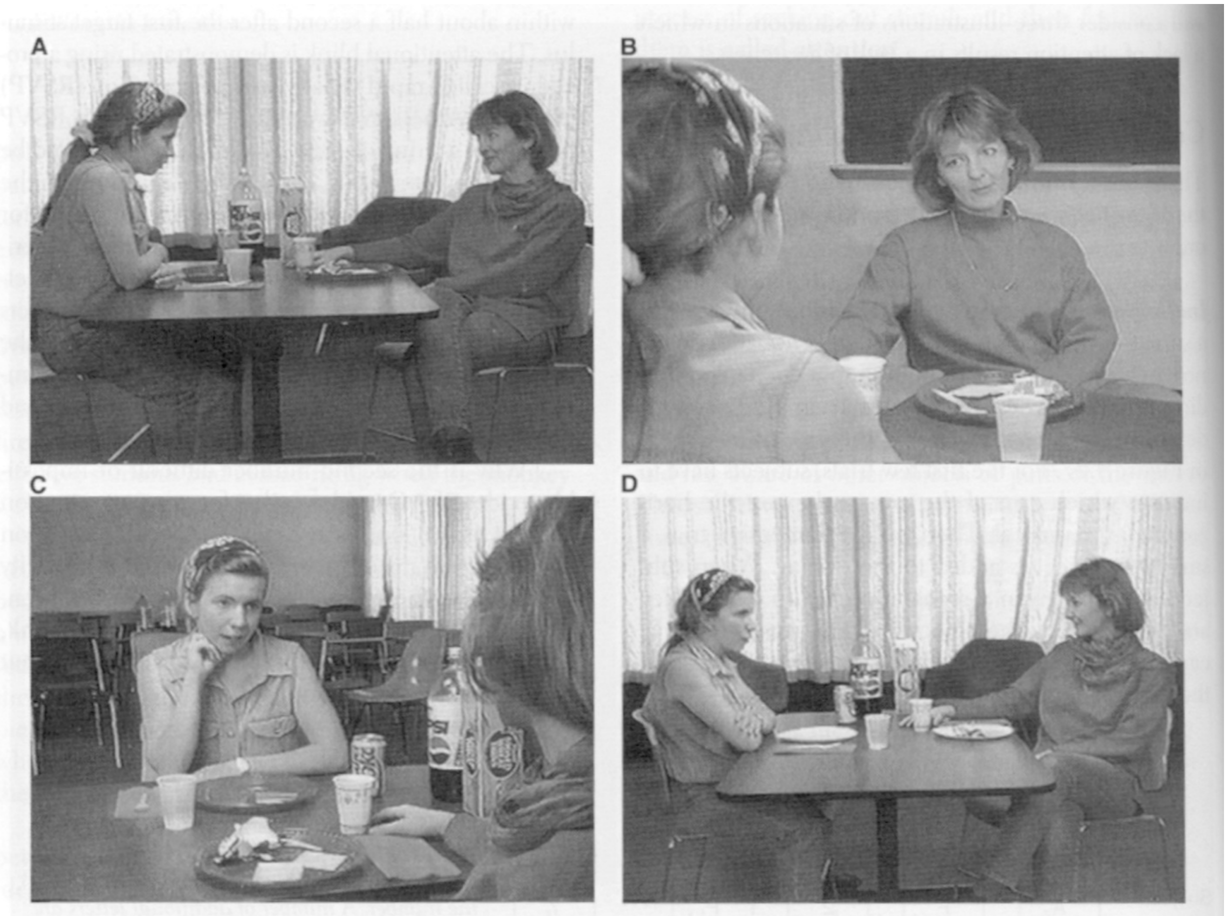
Attentional Blink

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

Change Blindness

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



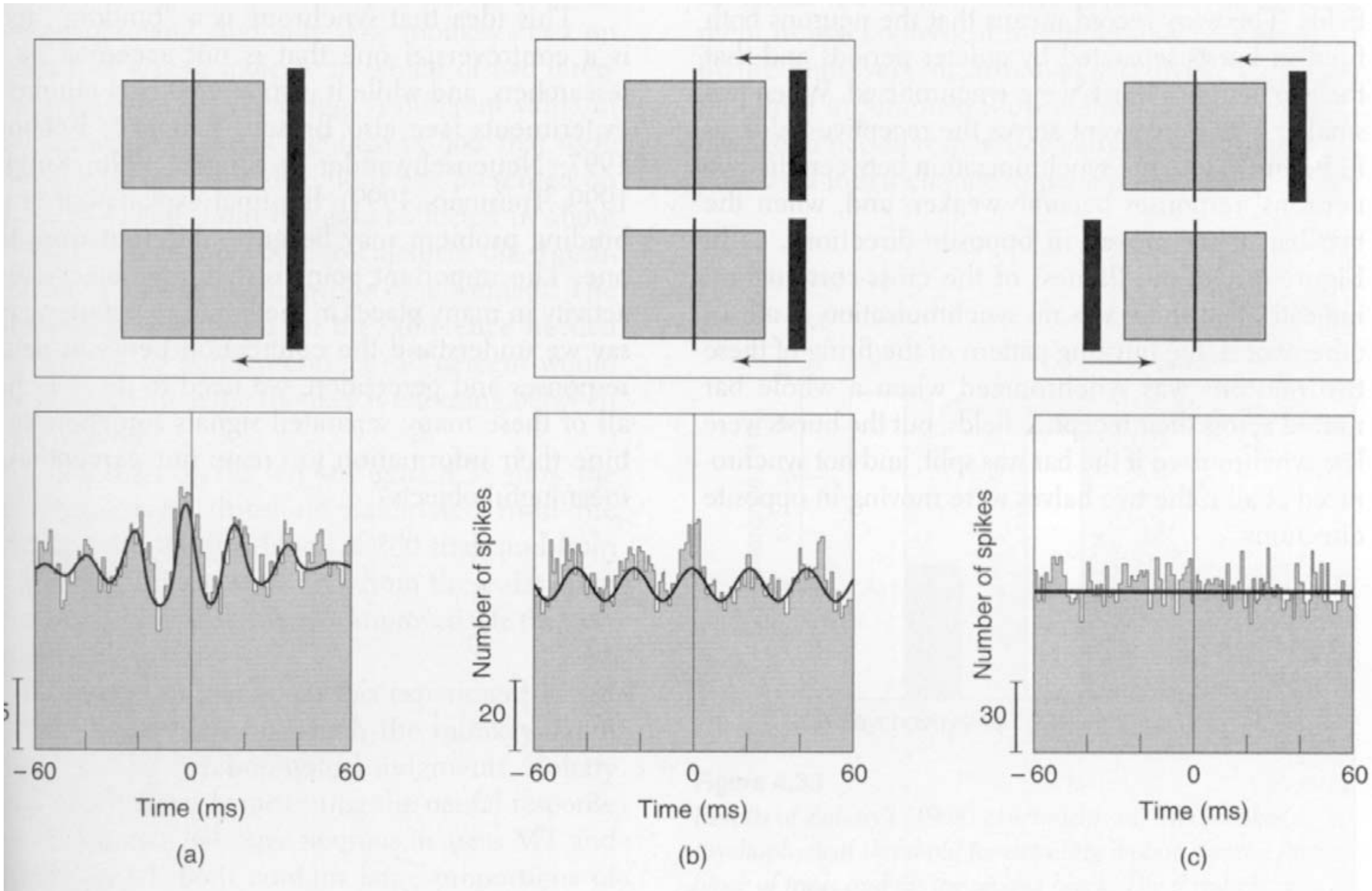
Examples

- https://www.youtube.com/watch?v=uO8wpm9HSB0
- https://www.youtube.com/watch?v=bh_9XFzbWV8
- https://www.youtube.com/watch?v=FWSxSQsspiQ

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



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