**Visual Object Recognition:**  
**Computational Models and Neurophysiological Mechanisms**  
**Neurobiology 130/230. Harvard College/GSAS 78454**

<table>
<thead>
<tr>
<th><strong>Web site:</strong></th>
<th><a href="http://tinyurl.com/visionclass">http://tinyurl.com/visionclass</a> (Class notes, readings, etc)</th>
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</thead>
<tbody>
<tr>
<td><strong>Location:</strong></td>
<td>Biolabs 2062</td>
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<tr>
<td><strong>Time:</strong></td>
<td>Mondays 03:30 – 05:30</td>
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**Lectures:**  
Faculty: Gabriel Kreiman and invited guests  
TA: Yuchen Xiao  
Class 6: Frederico A. C. Azevedo

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Gabriel Kreiman  
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617-919-2530  
Yuchen Xiao  
yxiao@g.harvard.edu  
Office Hours: After Class. Mon 05:30-06:30 or by appointment
Class 1. Introduction to pattern recognition [Kreiman]


Class 3. Lesion studies in animal models. Neurological studies of cortical visual deficits in humans. [Kreiman]

Class 4. Psychophysics of visual object recognition [Jiye Kim]

October 9: University Holiday

Class 5. Introduction to the thalamus and primary visual cortex [Camille Gomez-Laberge]

Class 6. Adventures into terra incognita. Neurophysiology beyond V1 [Frederico Azevedo]

Class 7. First steps into inferior temporal cortex [Carlos Ponce]

Class 8. From the highest echelons of visual processing to cognition [Leyla Isik]

Class 9. Correlation and causality. Electrical stimulation in visual cortex [Kreiman]


Class 11. Computer vision. Towards artificial intelligence systems for cognition [Bill Lotter]

Class 12. Vision and Language [Andrei Barbu]


FINAL EXAM
Visual processing [1-min review]

Kandel et al., *Principles of Neuroscience, 5th ed.*
Ventral pathway

Kandel et al., *Principles of Neuroscience*, 5th ed.
How do we go from oriented lines to complex shapes? 

Divide and conquer strategy: multiple small steps are required to solve a complex task

Hubel and Wiesel (1959) J. Physiol. 148: 574-591


*terra incognita*
Exhaustive exploration of the high dimensional image space is not possible with current techniques.
Response latency increases along the visual hierarchy

Each additional processing step takes ~15 ms

Schmolesky et al. 1998
Receptive field size increases along the ventral visual stream

Fig. 2. Schematic diagram showing convergence achieved by the forward projections in the visual system, and the types of representation that may be built by competitive networks operating at each stage of the system from the primary visual cortex (V1) to the inferior temporal visual cortex (area TE) (see text). Area TEO forms the posterior inferior temporal cortex. The receptive fields in the inferior temporal visual cortex (e.g. in the TE areas) cross the vertical midline (not shown). Abbreviation: LGN, lateral geniculate nucleus.
Receptive field size increases along the ventral visual stream
Visual area V2

- Illusory Contours
- Binocular disparity
- Border Ownership
- ...
Responses to illusory contours in area V2

Binocular disparity in V2

Depth cues influence object segmentation

Kandel et al., *Principles of Neuroscience*, 5th ed.
Border ownership in V2

Kandel et al., *Principles of Neuroscience*, 5th ed.
V4 lesions:

- moderate impairment in simple 2D shape discrimination
- Large deficit in 3D object recognition
- Loss of color constancy
- Deficits in the ability to detect less salient objects
Neurons in V4 show color selectivity
Neurons in V4 show color selectivity

Probing the responses of V2 and V4 neurons

Varied responses along the ventral visual stream

Increase in “complexity” of feature preferences along the ventral visual stream


Smax = maximum response to “simple stimulus”
MAX = max response to all stimuli
Smax/MAX = 1 → “simple responses”
Smax/MAX = 0 → “complex responses”
Increase in “complexity” of feature preferences along the ventral visual stream

<table>
<thead>
<tr>
<th></th>
<th>V2</th>
<th>V4</th>
<th>posterior IT</th>
<th>anterior IT</th>
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<tbody>
<tr>
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<td><img src="image1" alt="Image" /></td>
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<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
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Patients with pharmacologically intractable epilepsy

Multiple electrodes implanted to localize seizure focus

Targets typically include the temporal lobe (inferior temporal cortex, fusiform gyrus), medial temporal lobe (hippocampus, entorhinal cortex, amygdala and parahippocampal gyrus)

Patients stay in the hospital for about 7-10 days
Theory 1: Top-down influences and long recurrent feedback connections (> 200 ms)
Theory 2: Bottom-up approach and largely dependent on feedforward processing (< 200 ms)
Fast decoding of object information in human visual cortex

Liu et al. Neuron 2009
Neuropsychological evidence for object recognition in IT

### Apperceptive Agnosia

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<thead>
<tr>
<th>Model</th>
<th>Patient's drawing</th>
<th>Verbal identification of object</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(Circle)</td>
<td>“Circle”</td>
</tr>
<tr>
<td></td>
<td>(Square)</td>
<td>“Square”</td>
</tr>
<tr>
<td>3</td>
<td>(Diamond)</td>
<td>“Diamond”</td>
</tr>
<tr>
<td>4</td>
<td>(Three)</td>
<td>“Three”</td>
</tr>
<tr>
<td></td>
<td>(Four)</td>
<td>“Four”</td>
</tr>
</tbody>
</table>

- Ability to copy or match visual stimuli
- Deficiency of object perception
- Clinical interpretation: Cannot see object parts as a unified whole
- Clinical interpretation: Unable to construct sensory representations of visual stimuli

### Associative Agnosia

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<th>Verbal identification of object</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(Tea bag)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Tea bag)</td>
<td></td>
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</tbody>
</table>

- Cannot interpret, understand, or assign meaning to objects
- Sensory representation is created normally but cannot be associated with meaning, function, or utility

Kandel et al., *Principles of Neuroscience*, 5th ed.
Further reading


Original articles cited in class (see lecture notes for complete list)

(1) Write a critical comment on the paper
   What was right?
   What was wrong?
   Is the interpretation justified?
   Are the methods correct?
   Are all the controls there?
   Are there any confounding factors

(2) What would be a follow up study based on this paper?

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