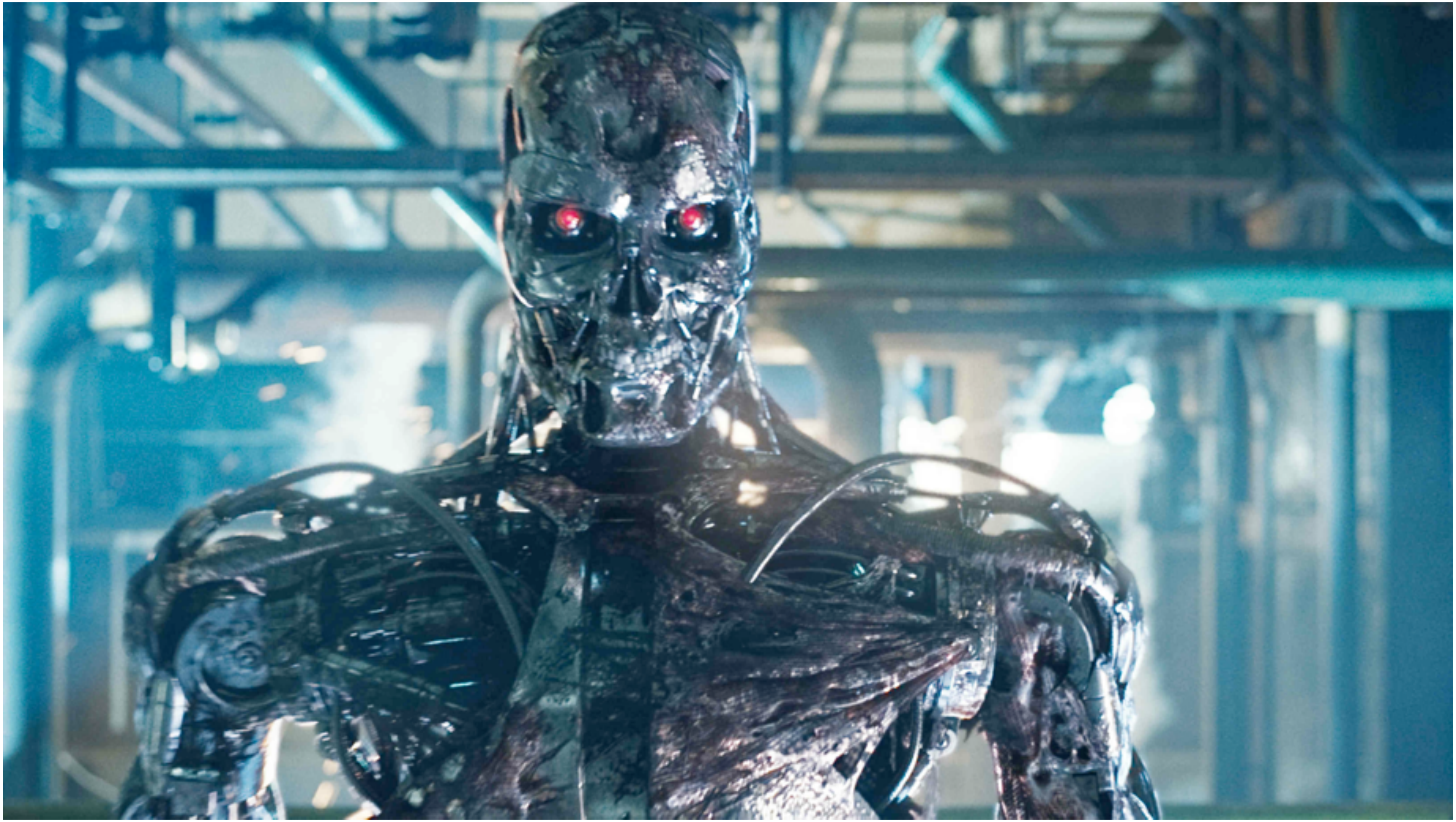
Computational Vision

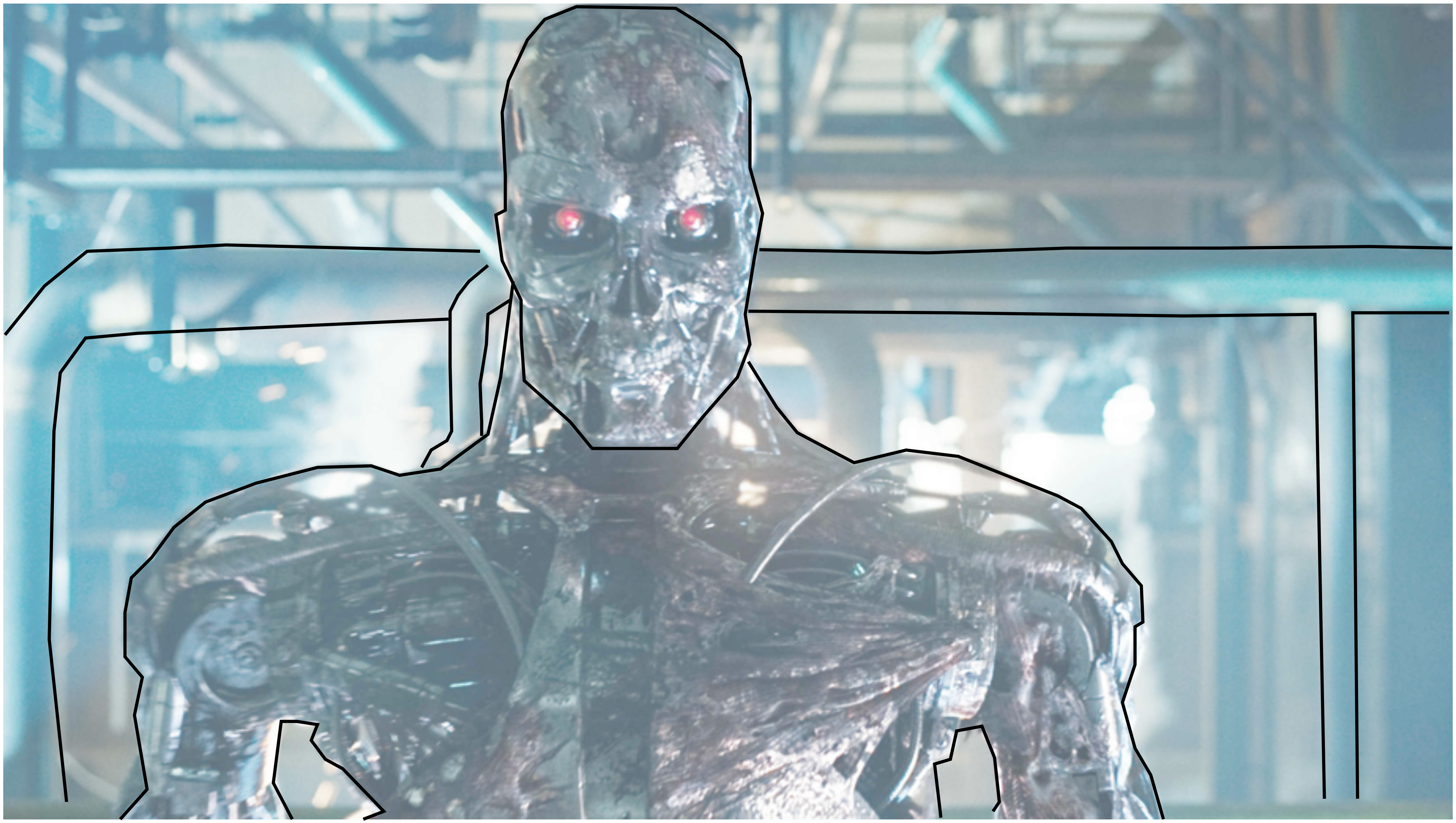
Primary visual cortex

- Orientation selectivity
- Spatial frequency
- Color opponency
- Normalization

General announcement (from your TA)



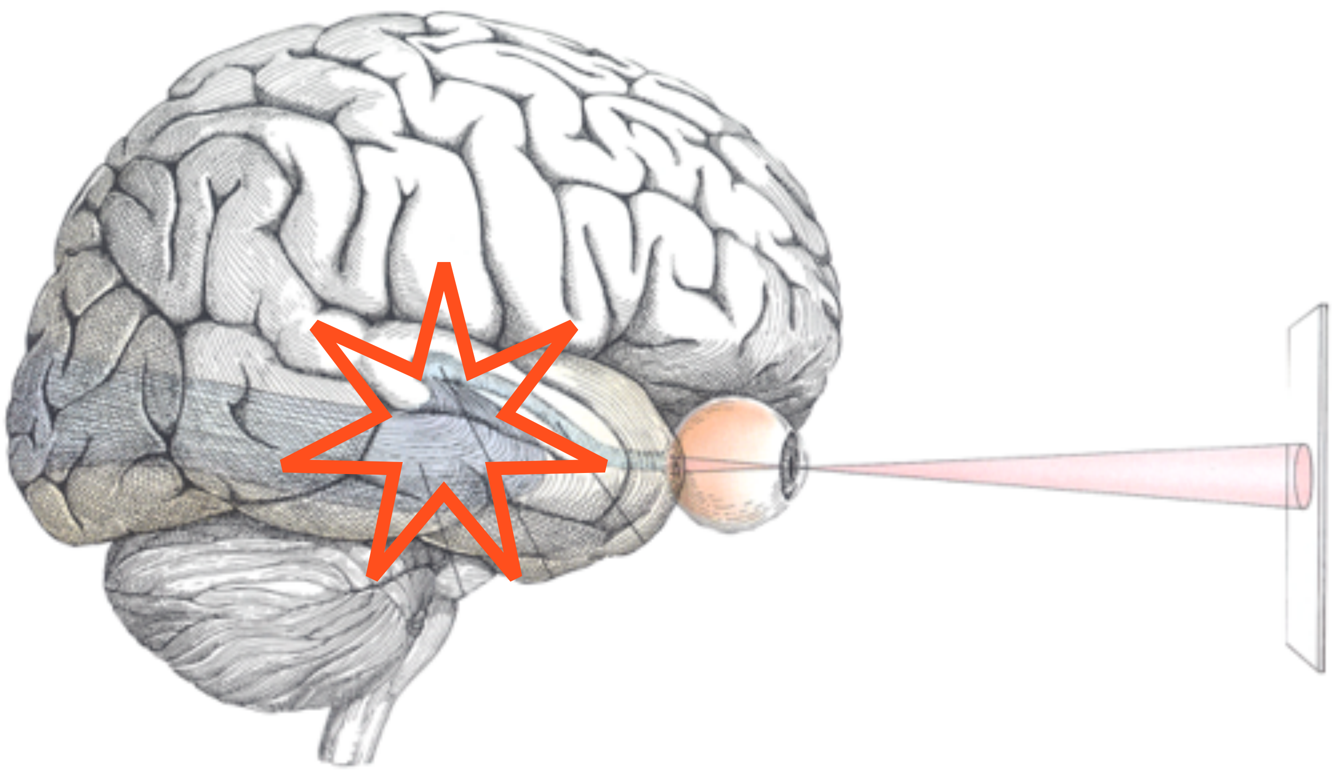
Boundary annotation

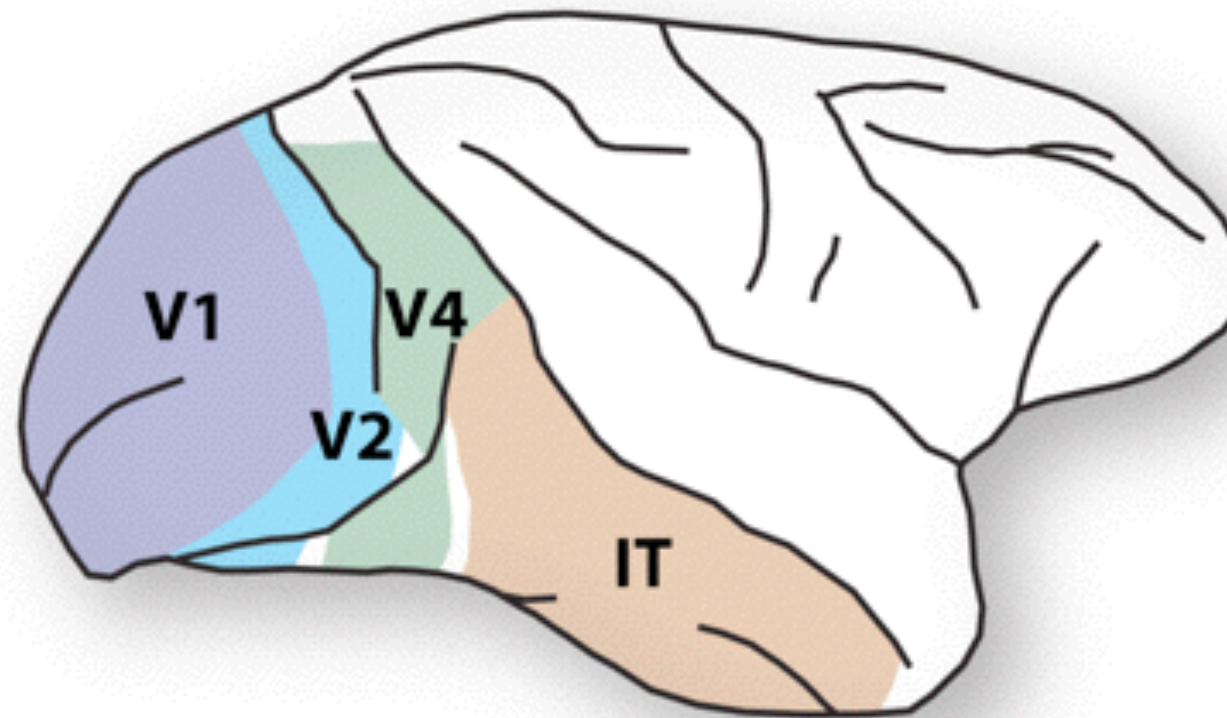


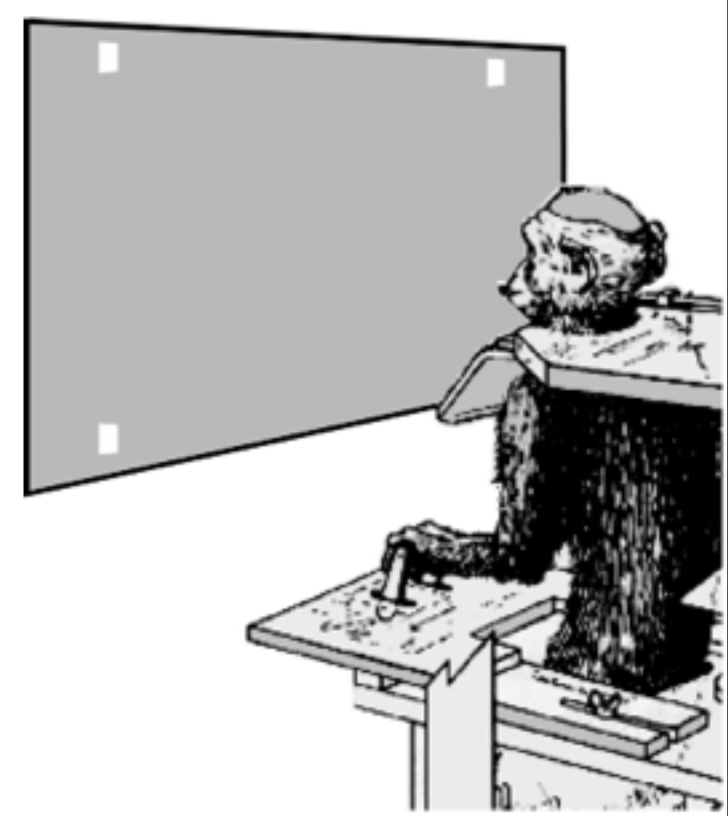
Here’s the deal

- Annotate the boundaries between things in 100 natural scenes
- $5 an hour (est. 10 hours of work)
- You have to complete within two weeks
- Speed bonus: $50 if you complete within one week
- contact: david_mely@brown.edu

Image source: DiCarlo



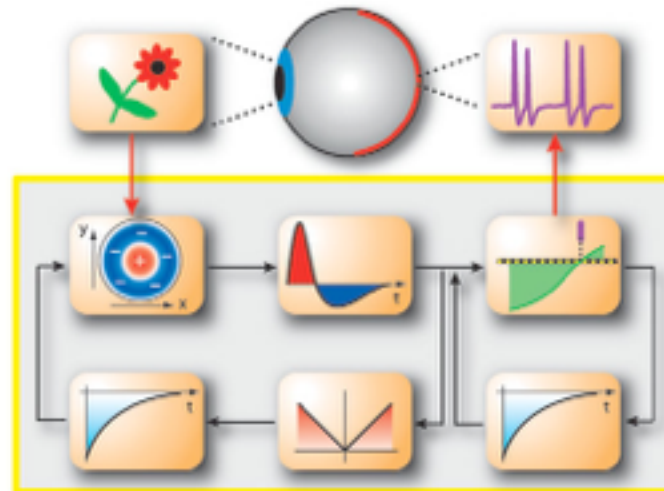


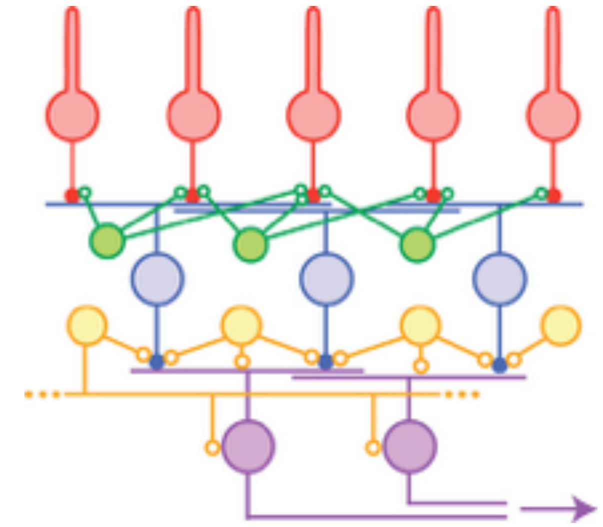

Adapted from Motter and Mountcastle 1981

The visual system

Computing with LGN

- Basic anatomy and physiology
- Center-surround processing
- Color opponency channels
- Convolution and filtering





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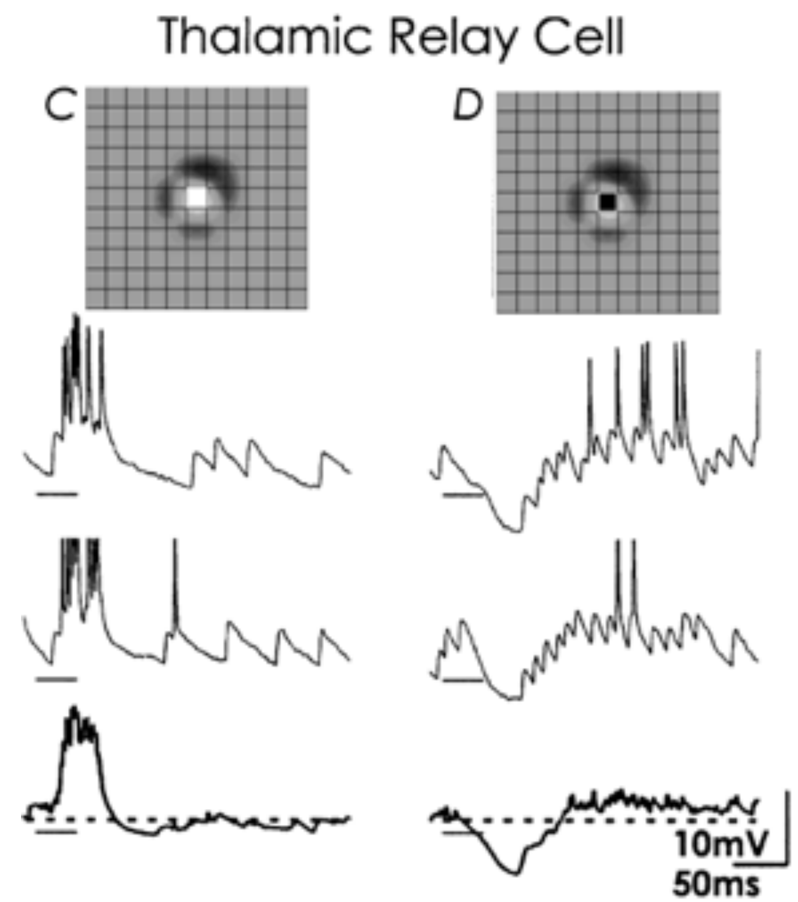
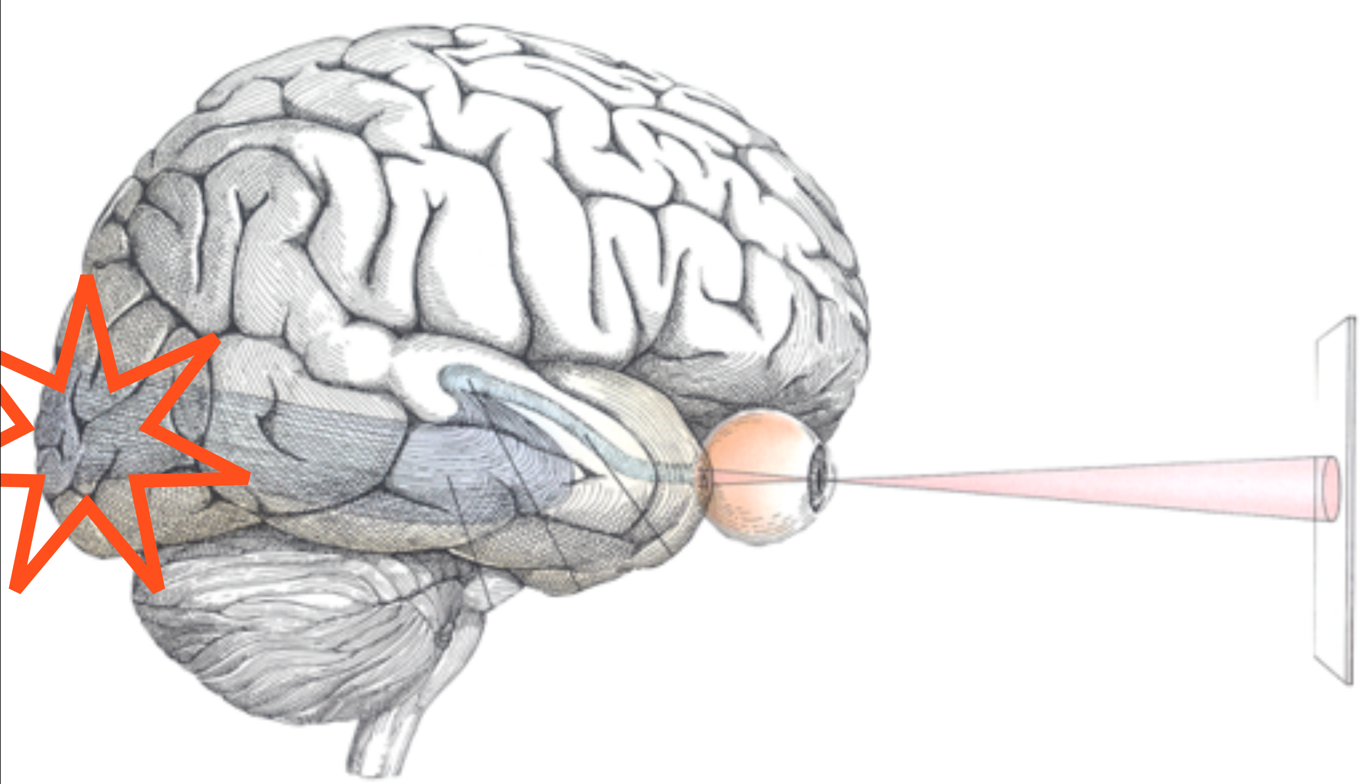
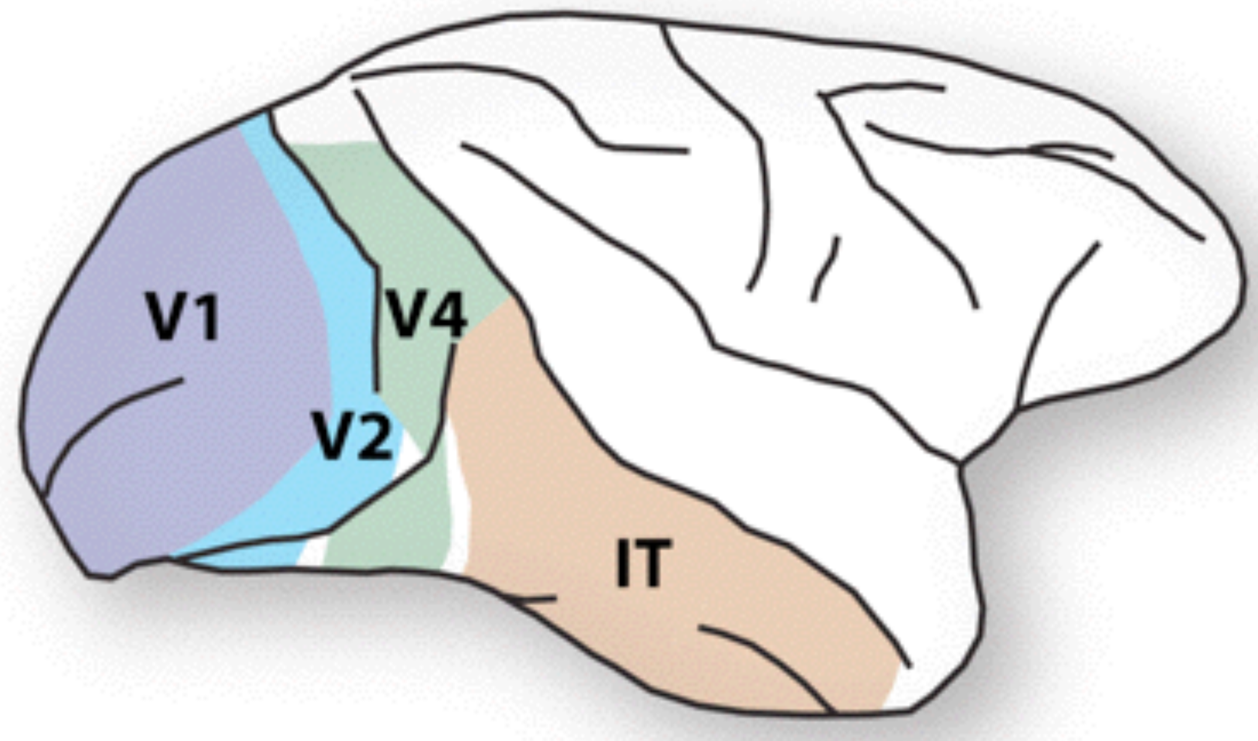
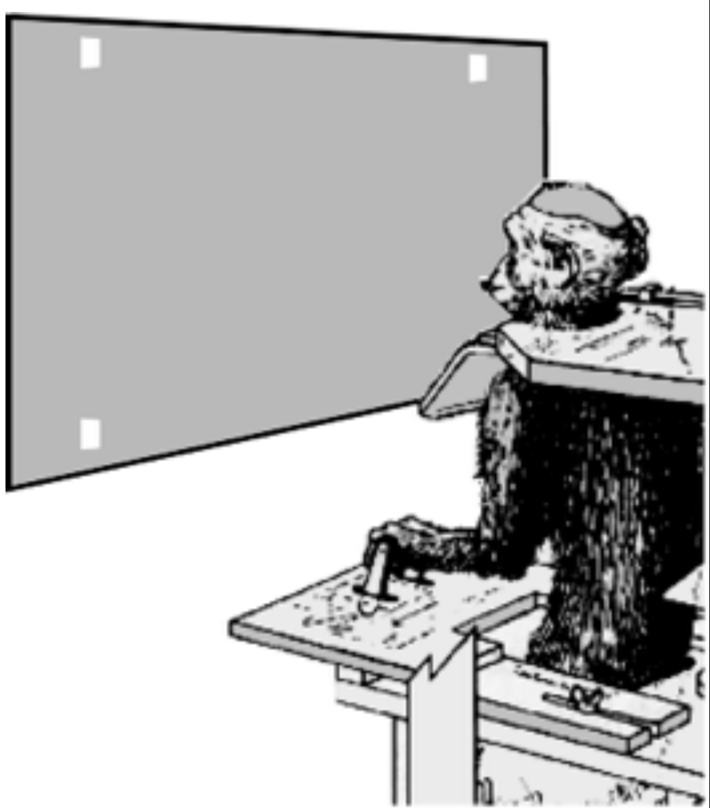


Image source: DiCarlo






Adapted from Motter and Mountcastle 1981

The visual system

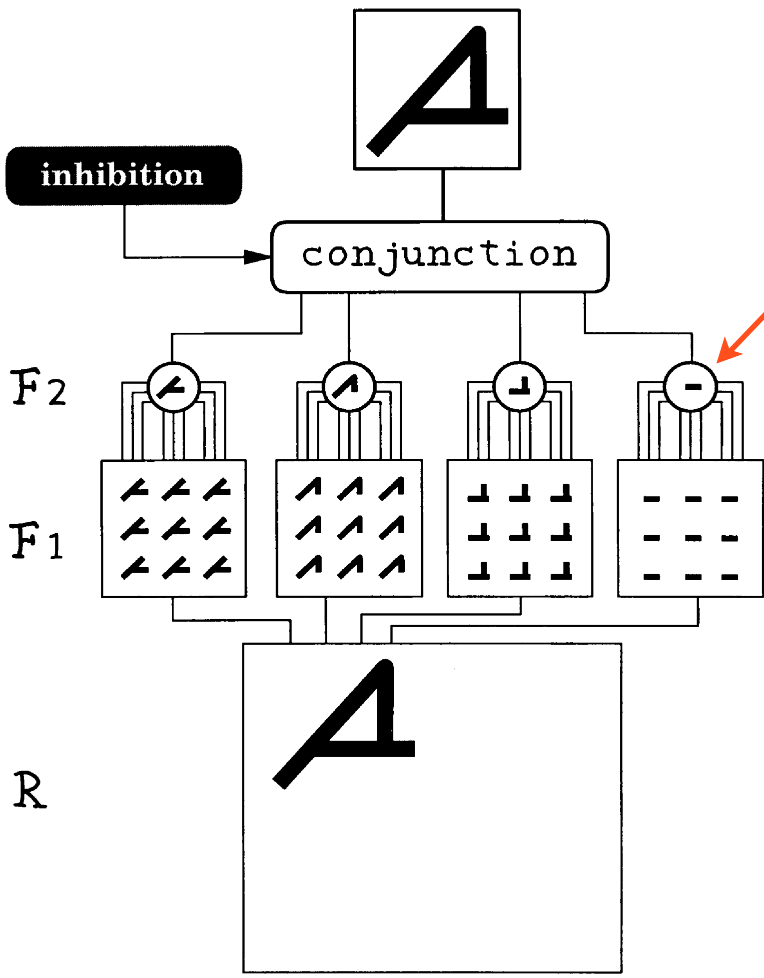
Seeing with brain maps

Orientation tuning

Source: Unknown

Visual analysis: Cortex vs. computers

Brains: Full-replication scheme



Computers: Convolution

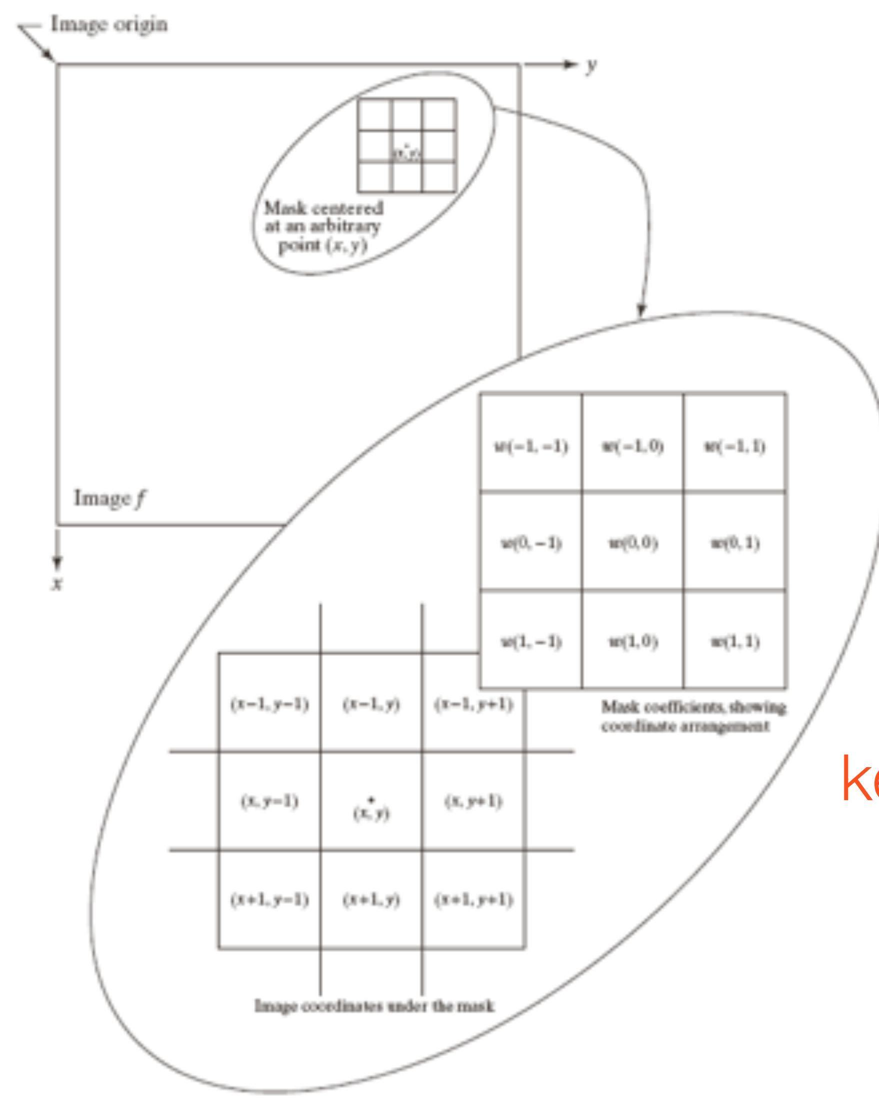
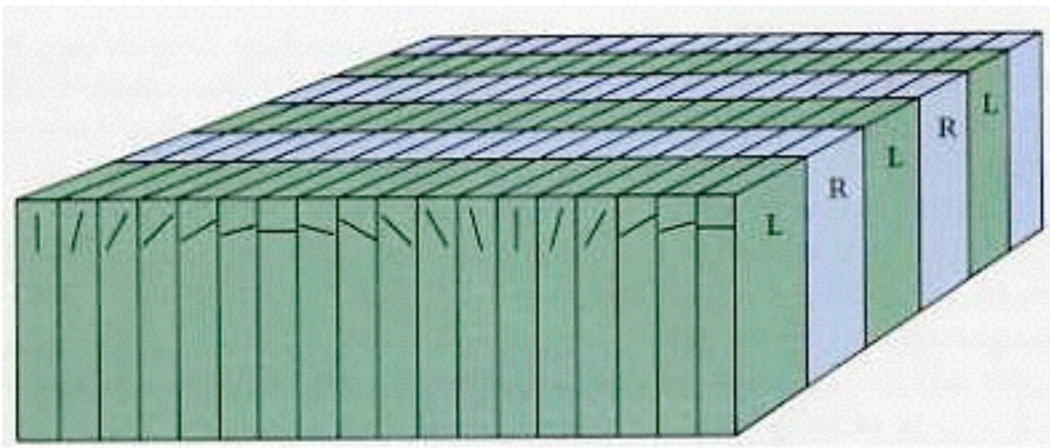
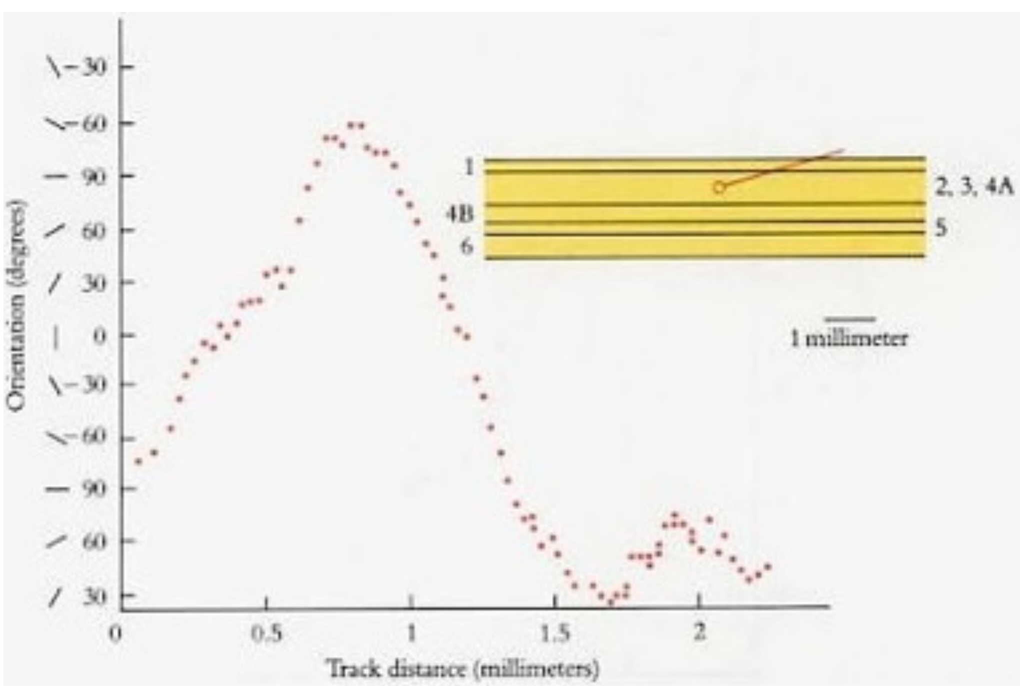


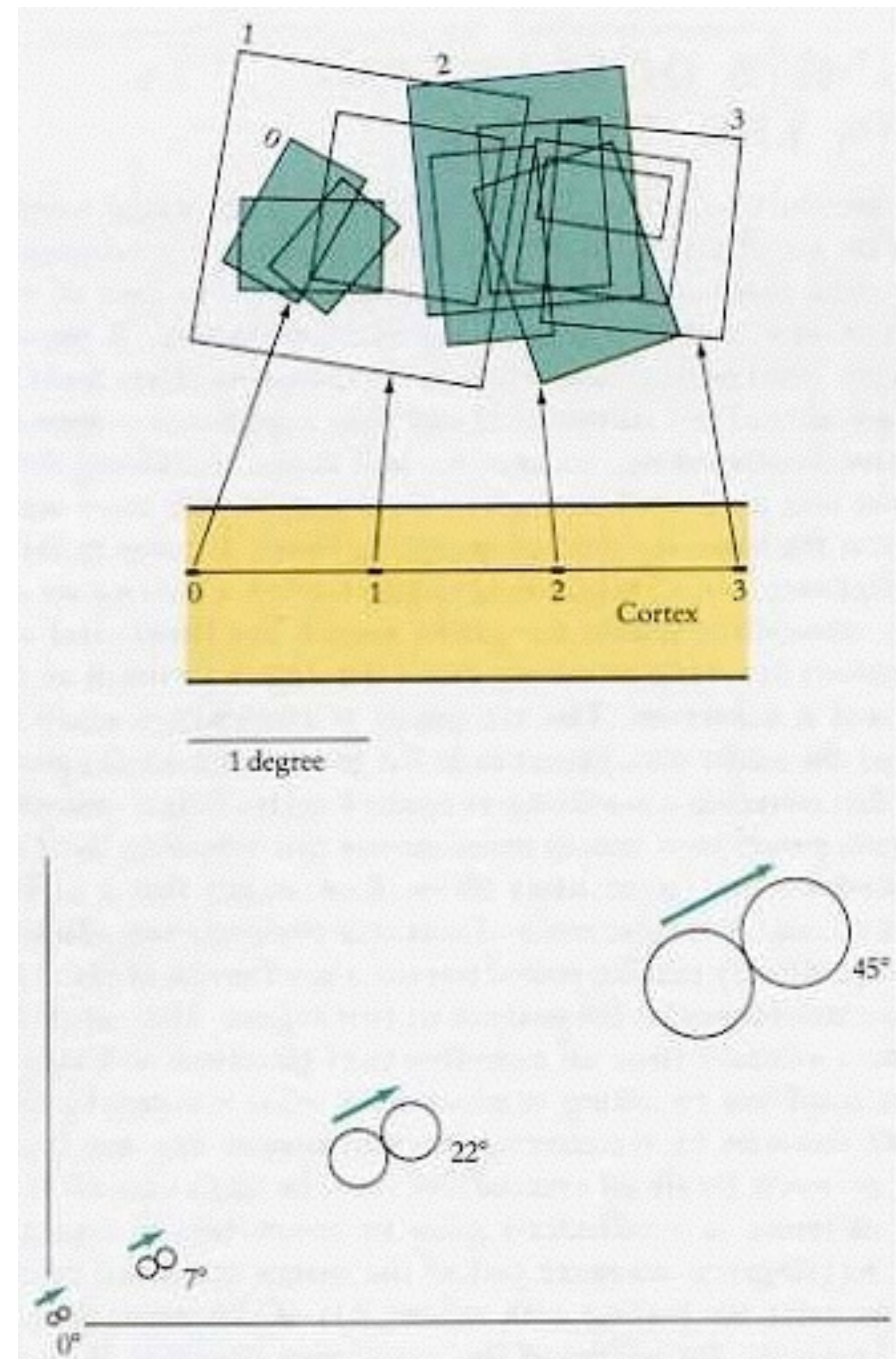
FIGURE 3.13 The mechanics of linear spatial filtering. The magnified drawing shows a 3 × 3 filter mask and the corresponding image neighborhood directly under it. The image neighborhood is shown displaced out from under the mask for ease of readability.

From feature detectors to population codes



Columnar organization





Source: David Hubel

Computing neurons

$$y(x) = \mathbf{w}^T \mathbf{x}$$

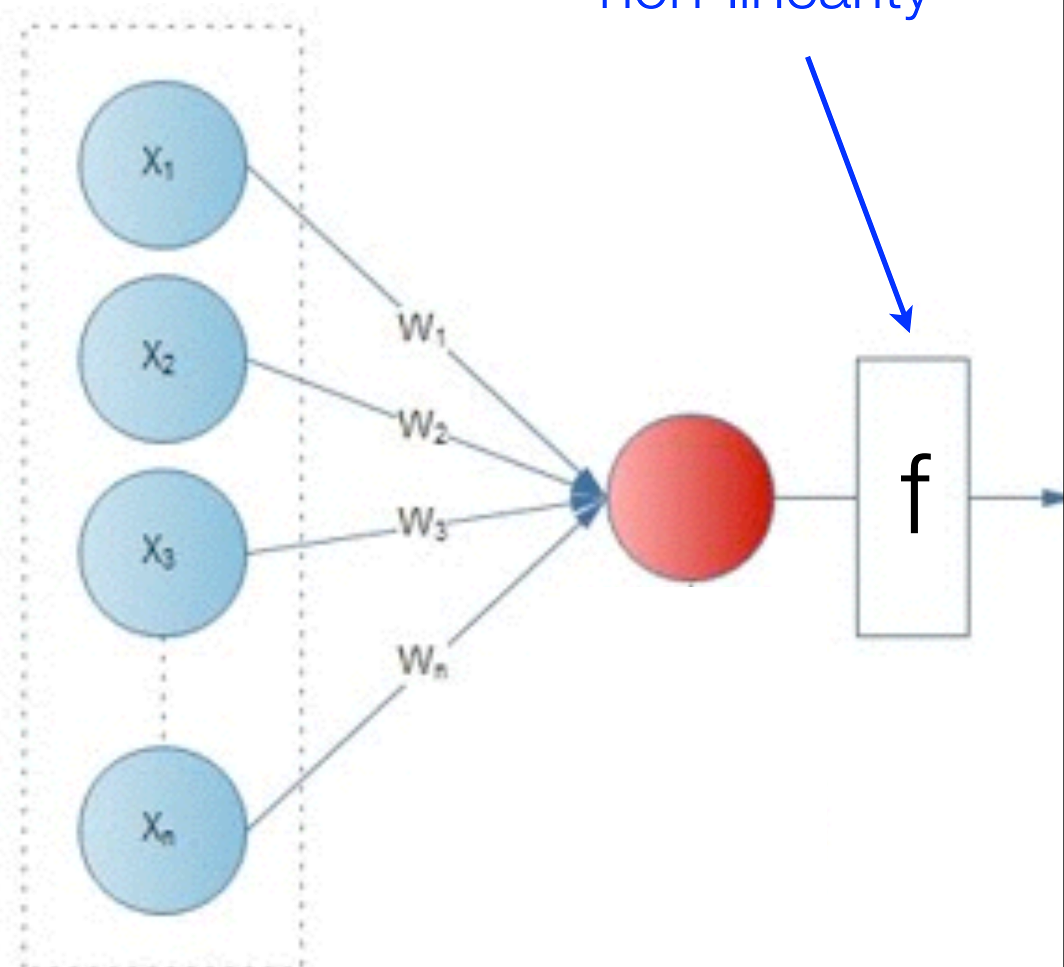
$$y(x) = \sum w_i x_i$$

Synaptic efficacies

Summation at the soma

Spike trains / firing rates coming from each afferent neuron

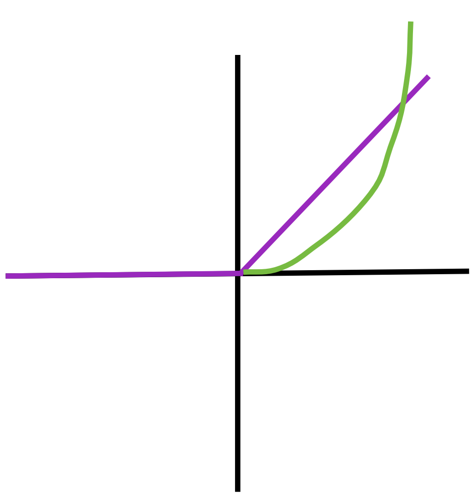
Spike generation process introduces non-linearity



several layers of processing in the retina

ganglion cells = retinal output / LGN

rectification



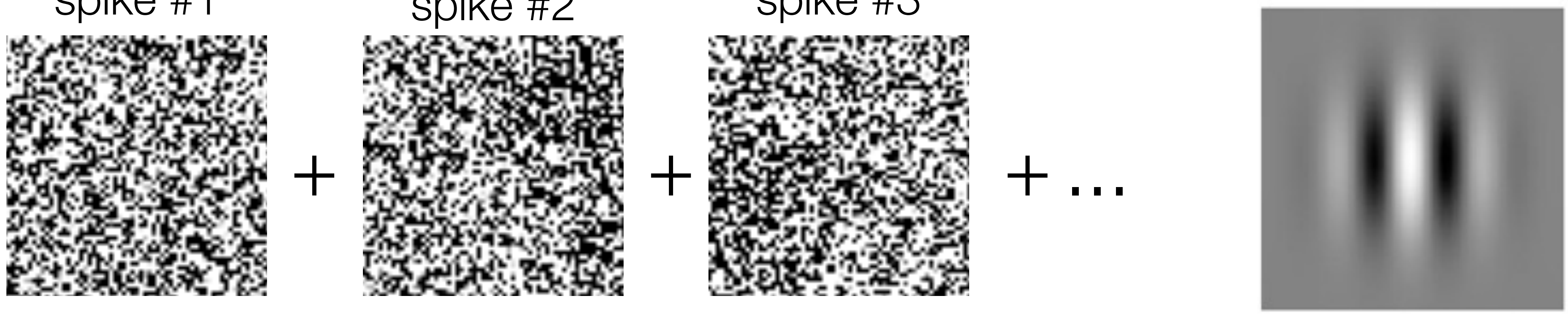
f(u) = u if u>0 and 0 otherwise

f(u) = u^2 if u>0 and 0 otherwise

Reverse-correlation / spike-triggered average

finding out the neuron selectivity = template

$$
\begin{aligned}
y(x) &= \sum w_i x_i \\
&= \mathbf{w} \cdot \mathbf{x} \\
&= ||\mathbf{w}||\,||\mathbf{x}|| \cos(\theta)
\end{aligned}
$$



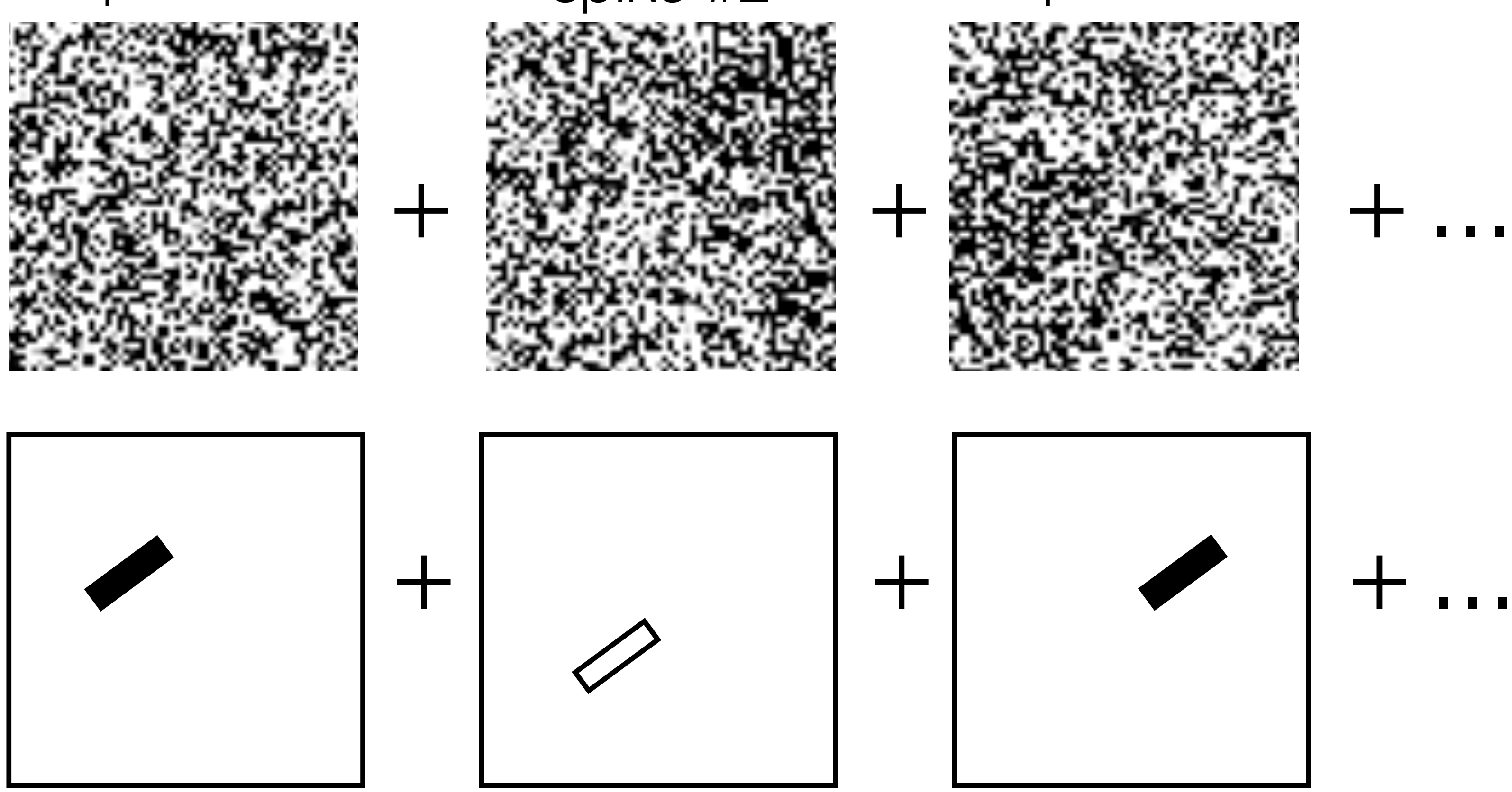
Reverse-correlation / spike-triggered average

finding out the neuron selectivity = template

$$\begin{aligned} y(x) &= \sum w_i x_i \\ &= \mathbf{w} \cdot \mathbf{x} \\ &= ||\mathbf{w}||\,||\mathbf{x}|| \cos(\theta) \end{aligned}$$

spike #1 spike #2 spike #3

t ms before spike



Reverse-correlation / spike-triggered average

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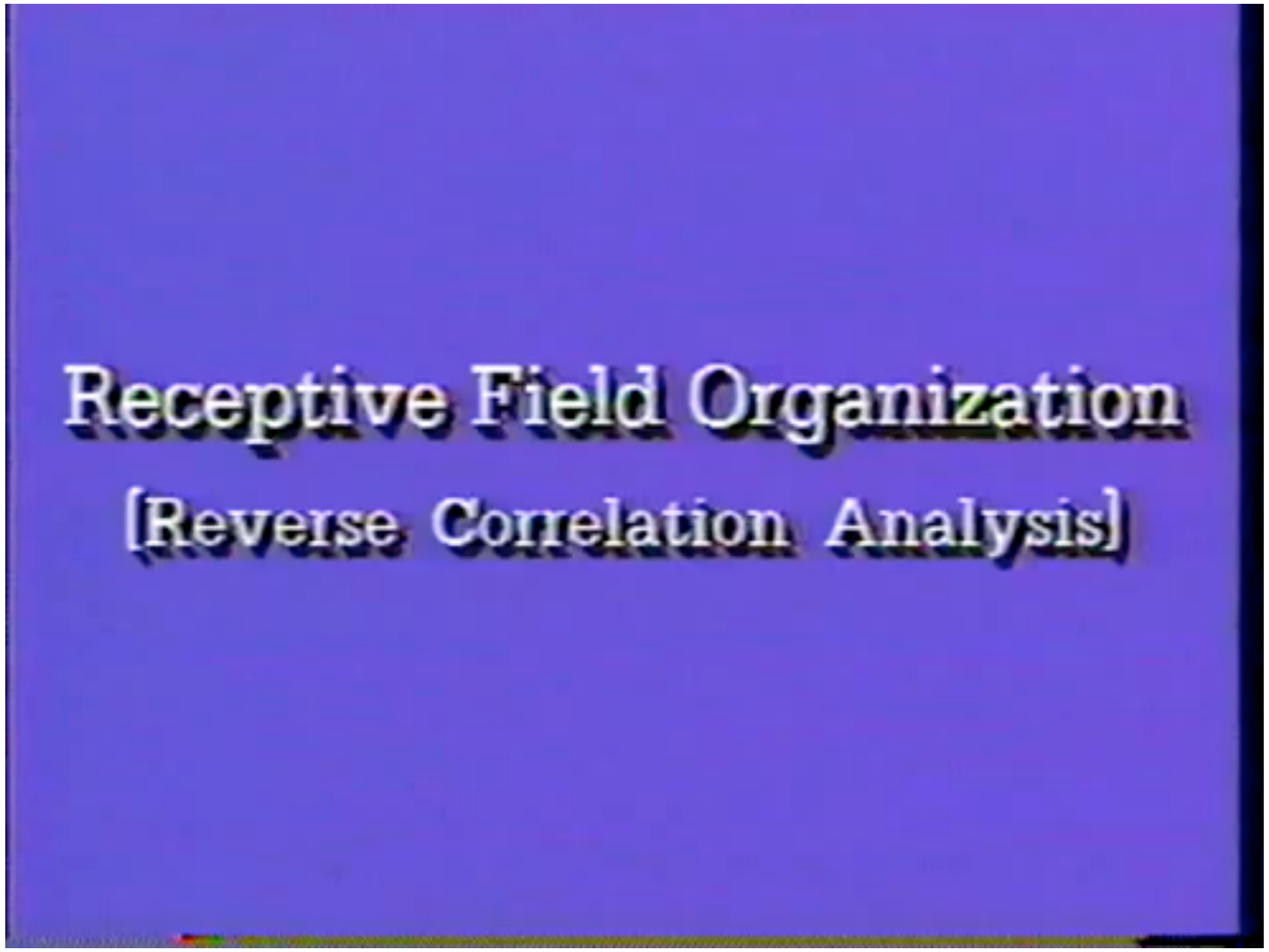
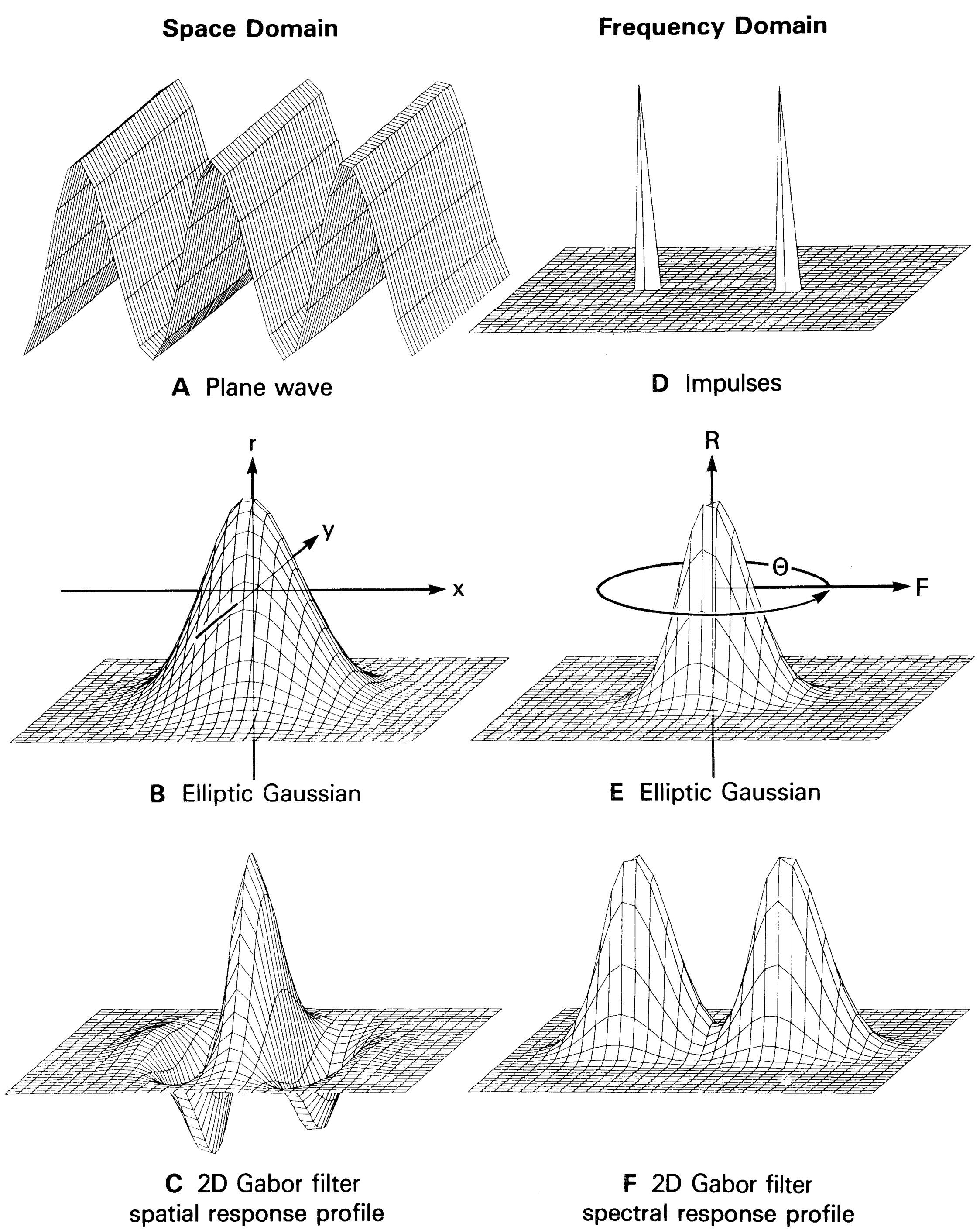
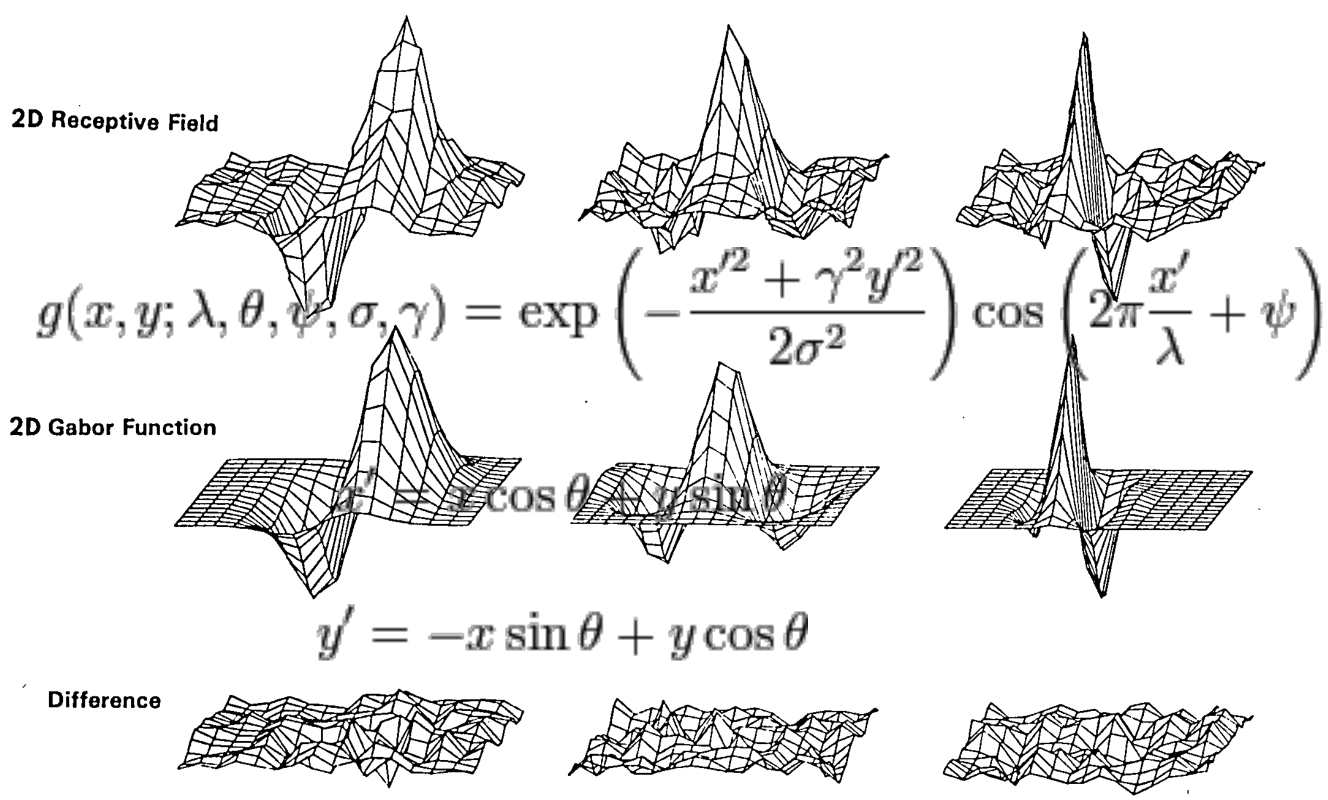


Gabor functions as models of simple cells



Gabor filters optimize the general uncertainty relations for joint spatial-spectral information resolution



$$g(x, y; \lambda, \theta, \psi, \sigma, \gamma) = \exp\left(-\frac{x'^2 + \gamma^2 y'^2}{2\sigma^2}\right) \cos\left(2\pi \frac{x'}{\lambda} + \psi\right)$$

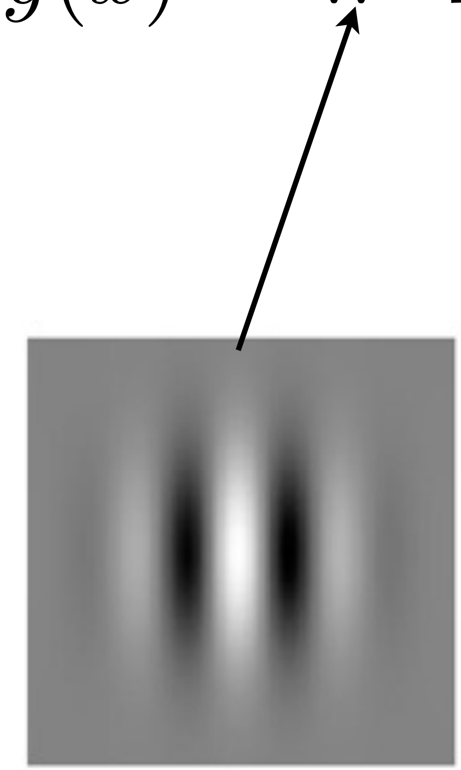
$$x' = x \cos\theta + y \sin\theta$$

$$y' = -x \sin\theta + y \cos\theta$$

Jones & Palmer '87

Gabor functions as models of simple cells

$$y(x) = \mathbf{w}^T \mathbf{x}$$



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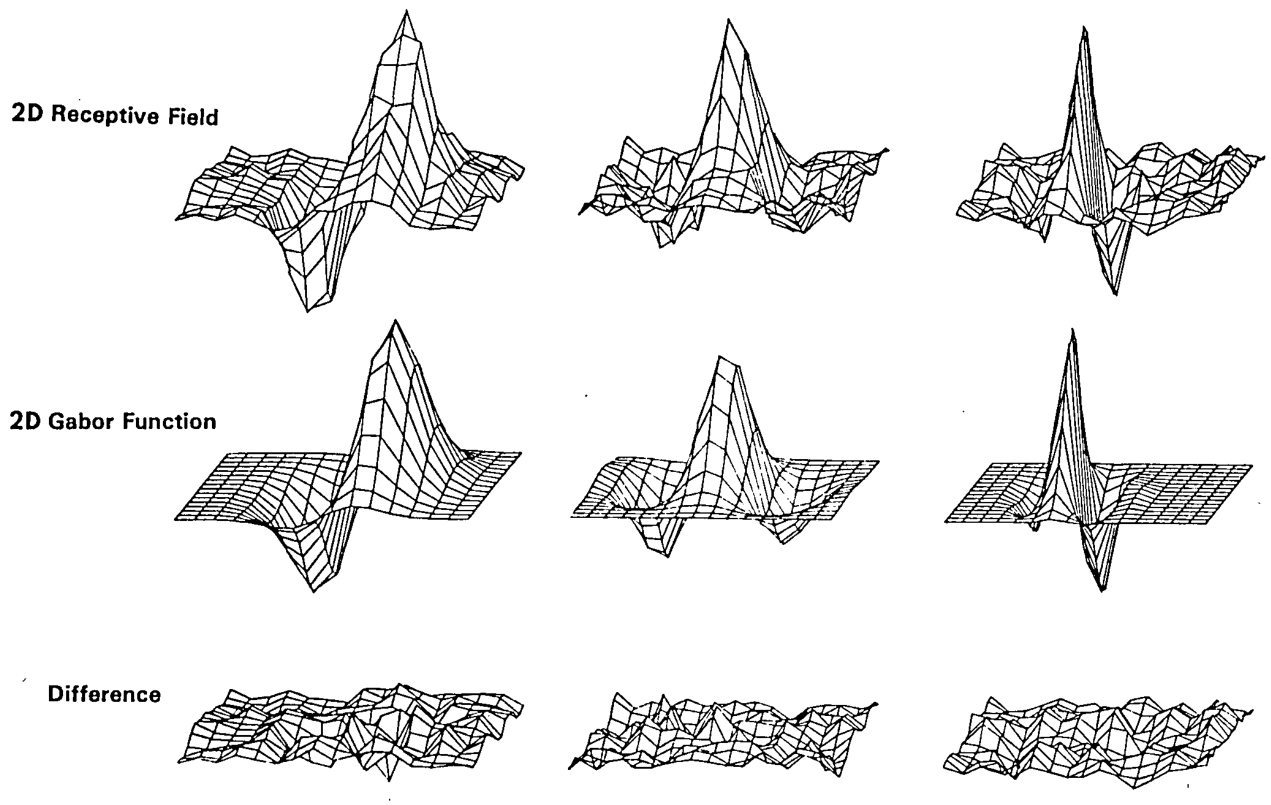
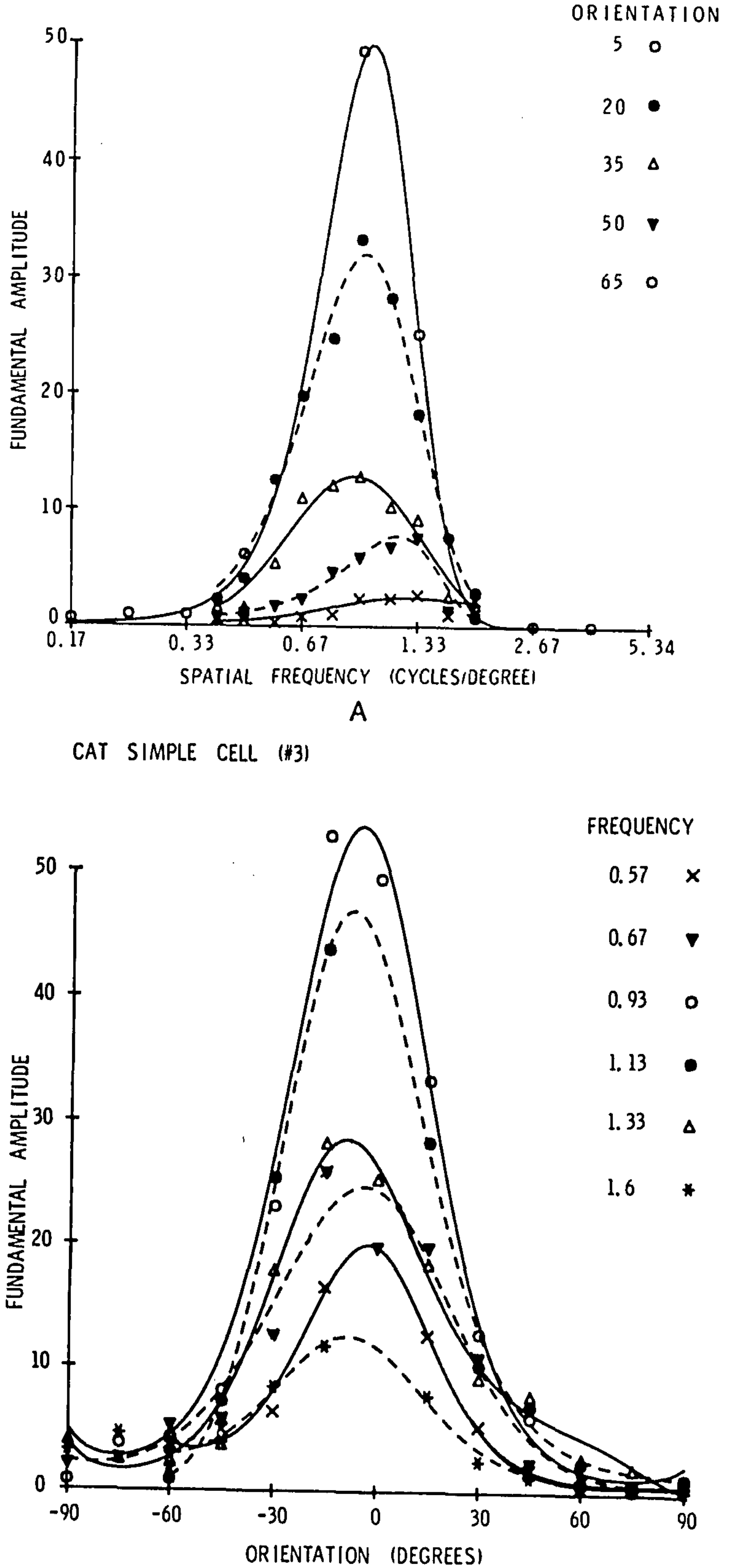


Jones & Palmer ’87

Tuning in the visual cortex

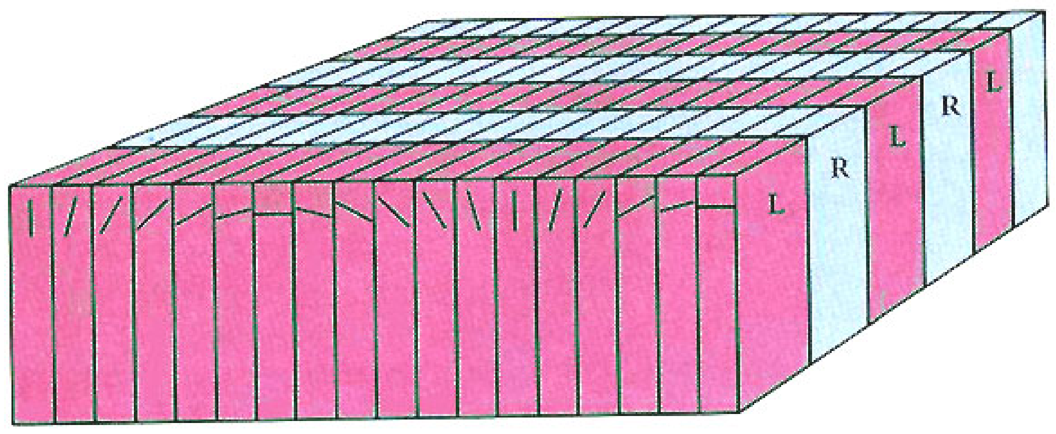
Next assignment!



Webster & Devalois 1985

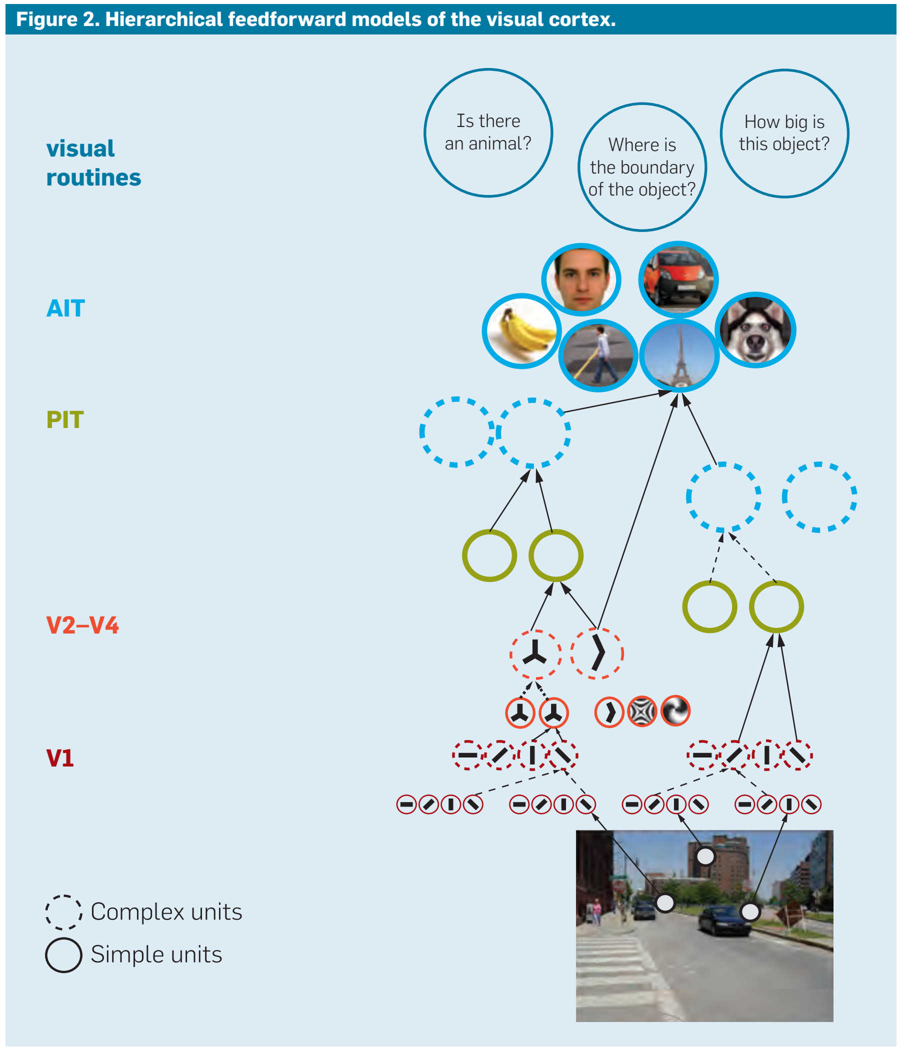
Computing with V1

Gabor filters

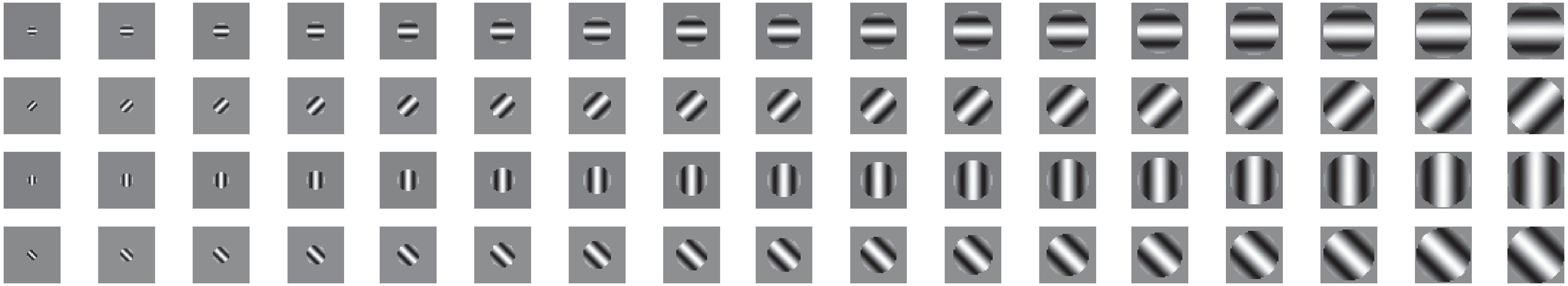


Orientation and ocular dominance columns

Figure 23. The ice-cube model of the cortex. It illustrates how the cortex is divided, at the same time, into two kinds of slabs, one set of ocular dominance (left and right) and one set for orientation. The model should not be taken literally: Neither set is as regular as this, and the orientation slabs especially are far from parallel or straight.

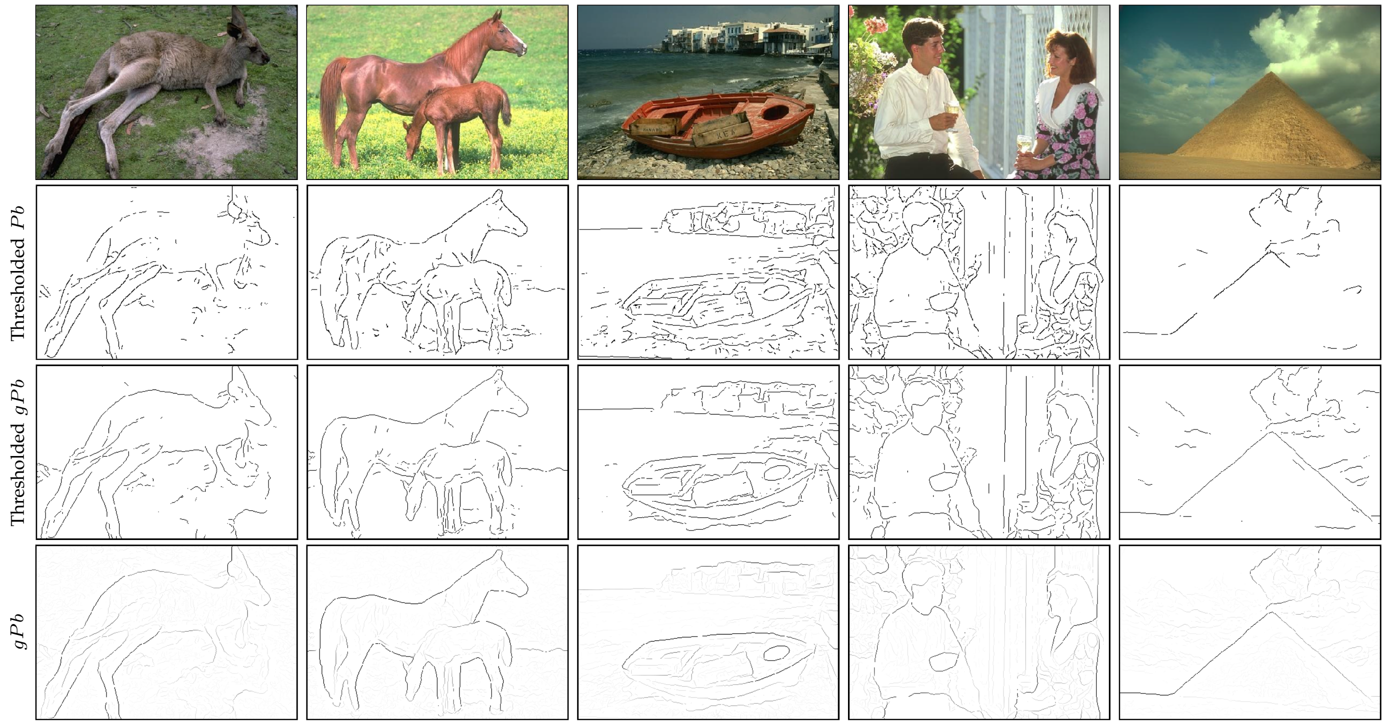


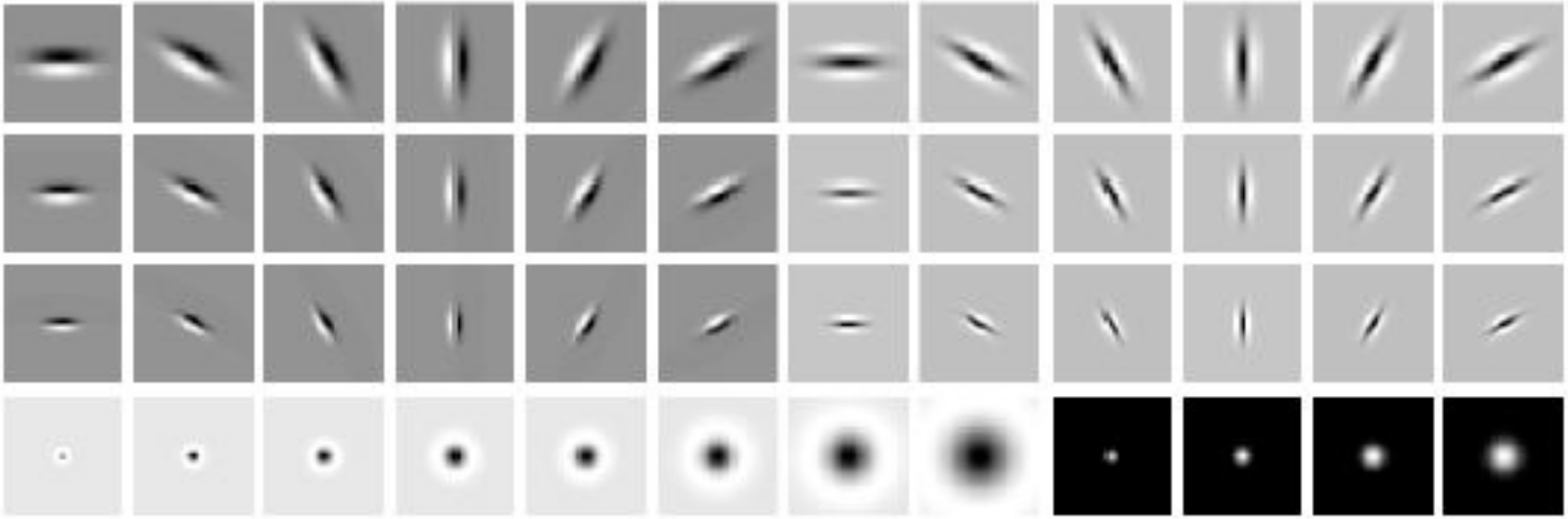
Gabor filters at multiple phases (one phase shown), orientations and spatial frequencies/scales (parameters derived from available experimental data)



Computing with V1

Gaussian derivatives

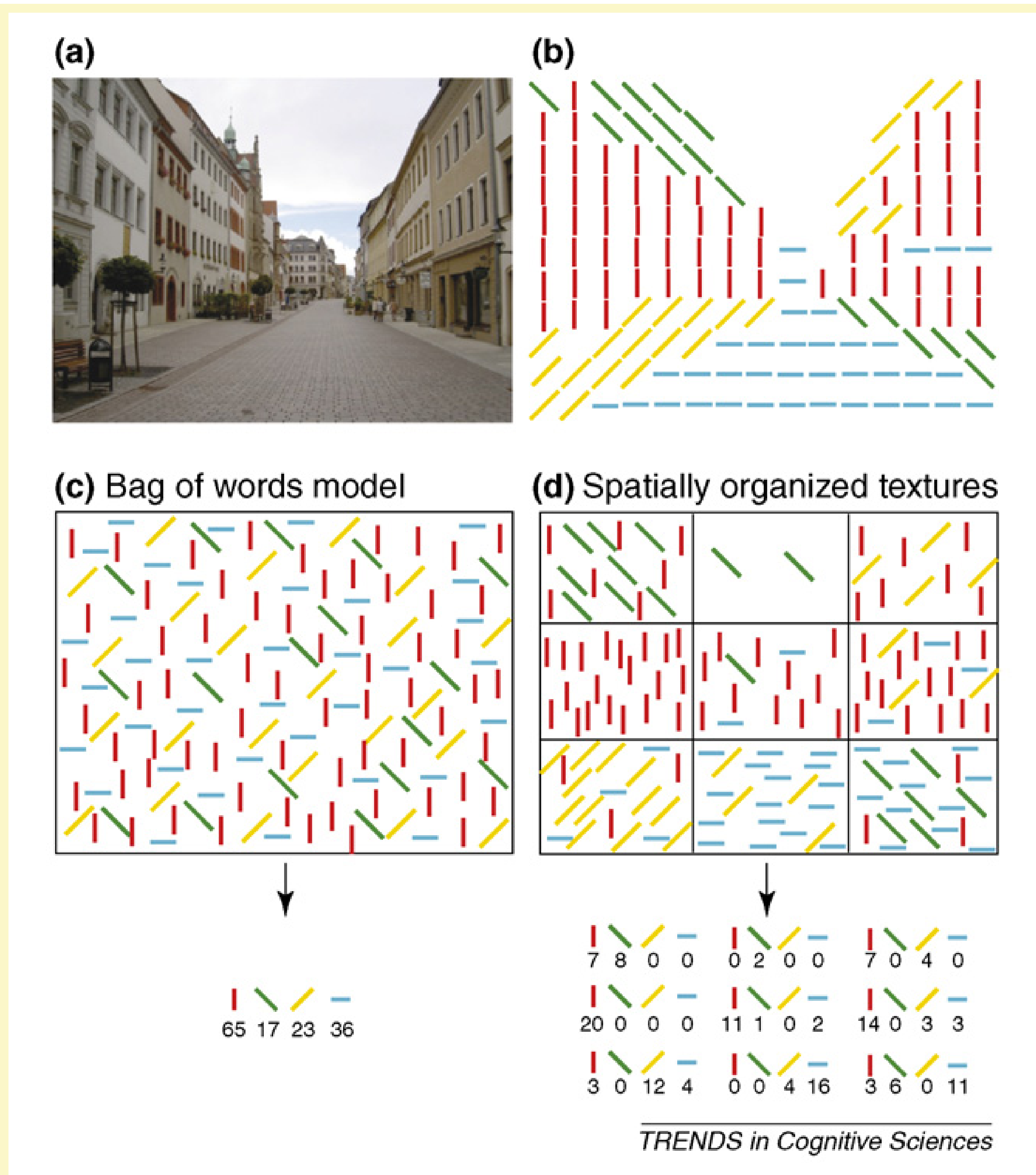


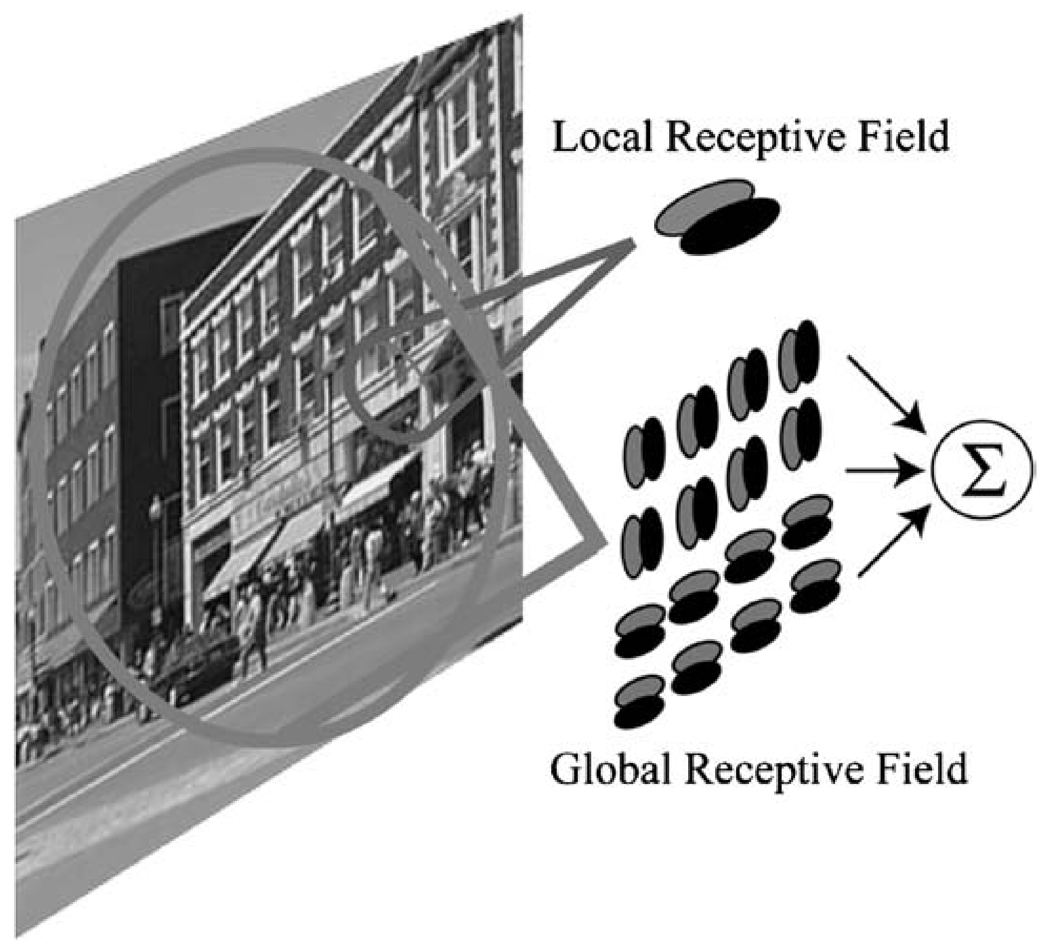


source: http://www.robots.ox.ac.uk/~vgg/research/texclass/filters.html

Computing with V1

Gist descriptor





source: Torralba & Oliva 2006 2007