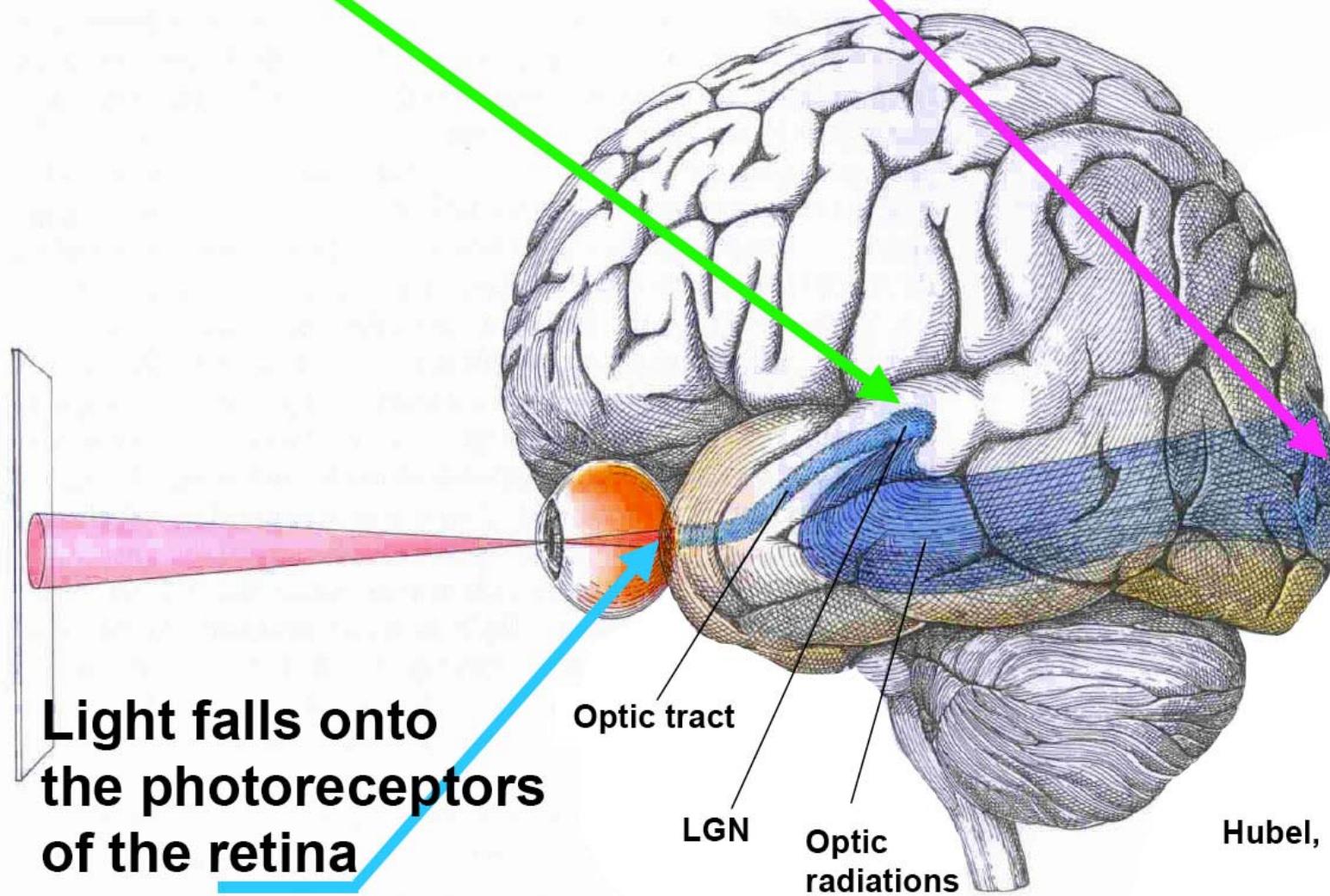


# **A brief introduction to Computational Neuroscience**

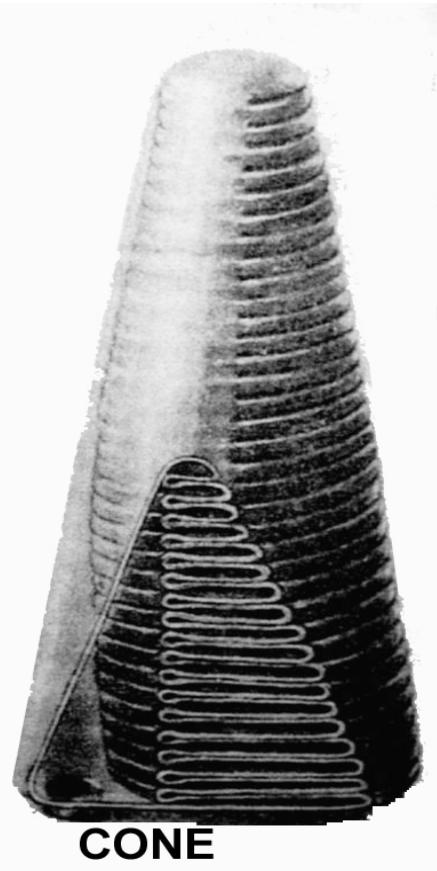
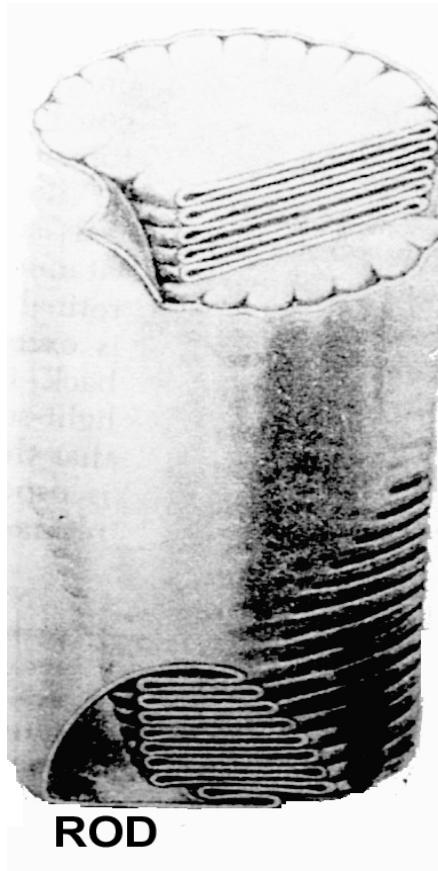
Aaditya Rangan  
**Courant, NYU**

# Visual Pathway

**Thalamus (LGN) serves strategic role in gating of information flow to cortex**

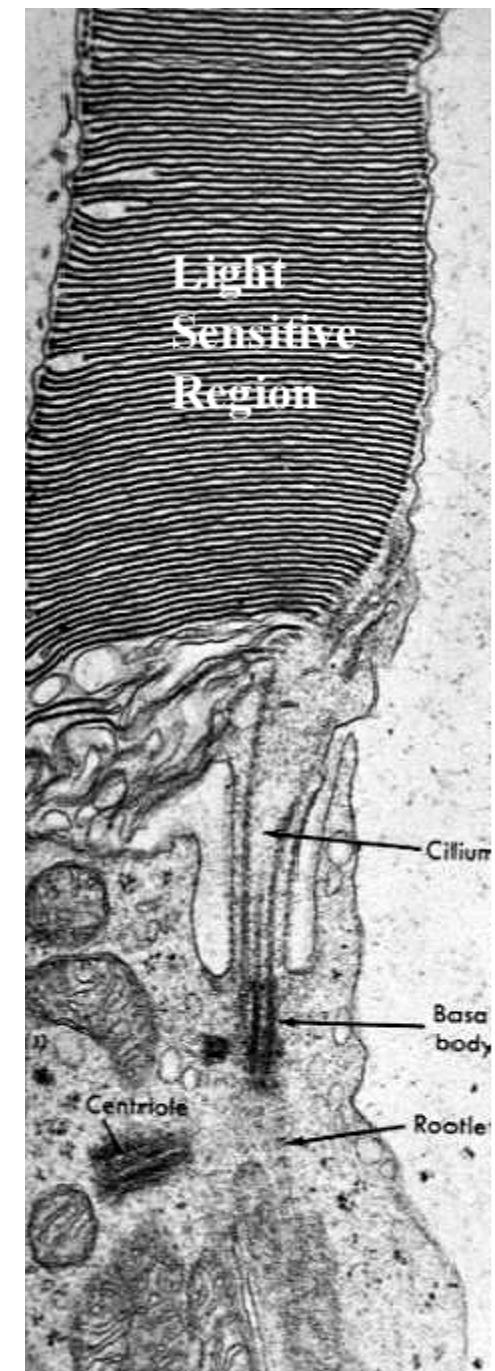


# Eye: Retinal Cells

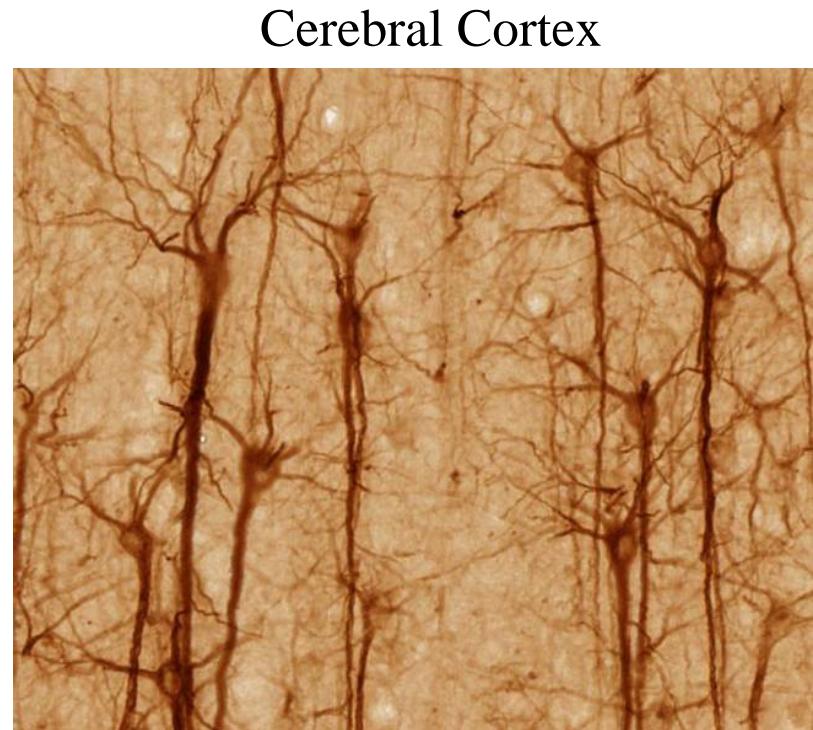
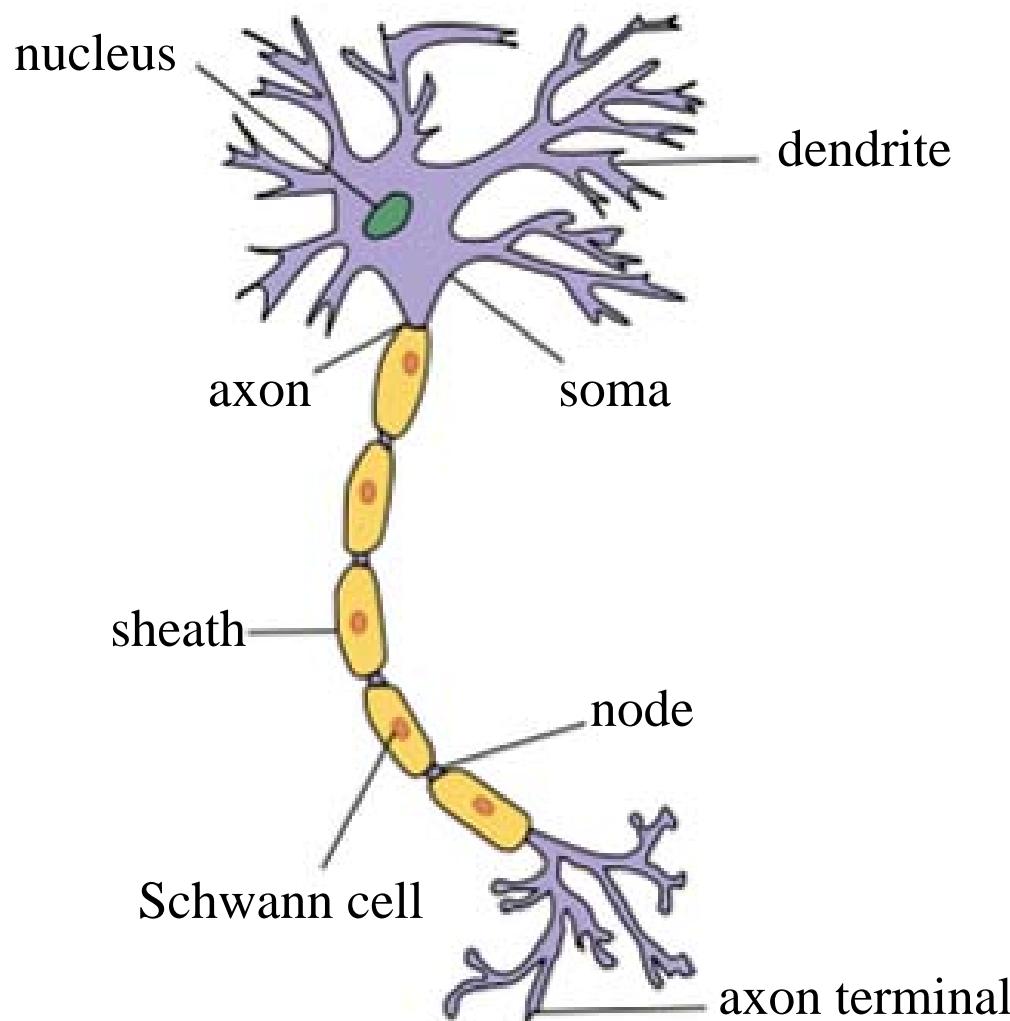


Black and White

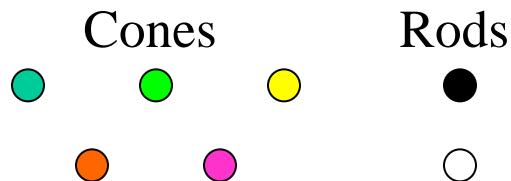
Color Sensitive  
(found in most animals!)



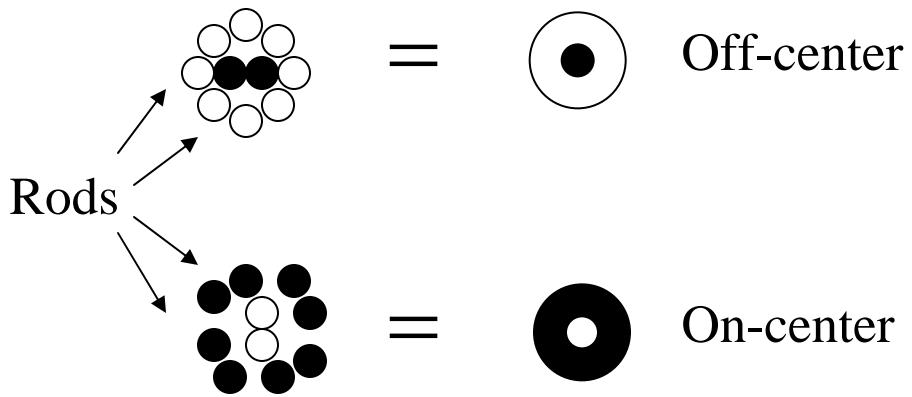
**Brain = 1.5mTONS of neurons! (okay, 1.5 pounds)**



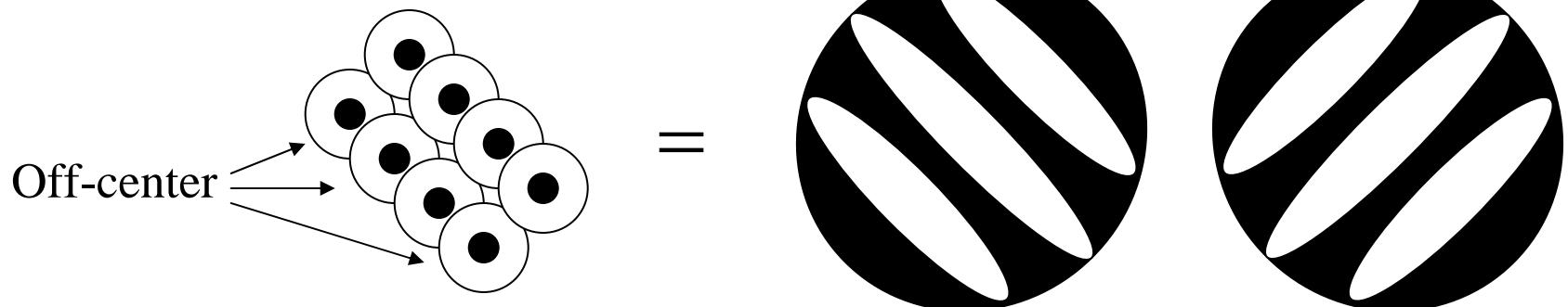
# Retinal Receptive Field



# Thalamic Receptive Field



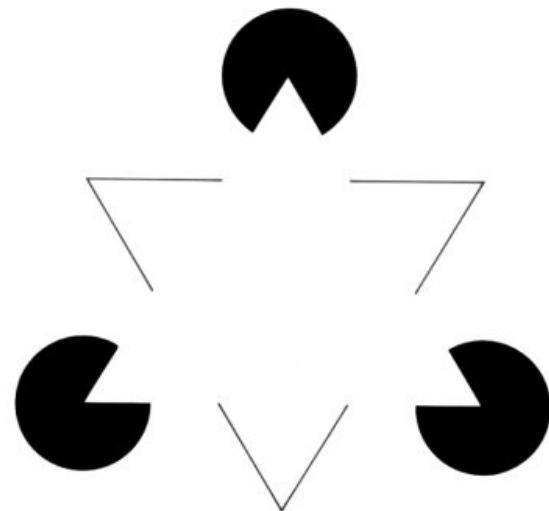
# Cortical Receptive Field

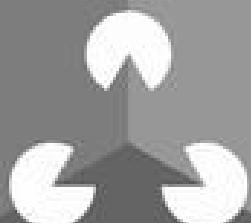
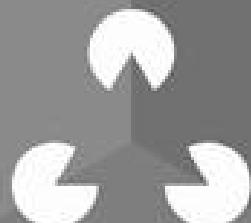


At low contrast, and over intermediate time-scales,

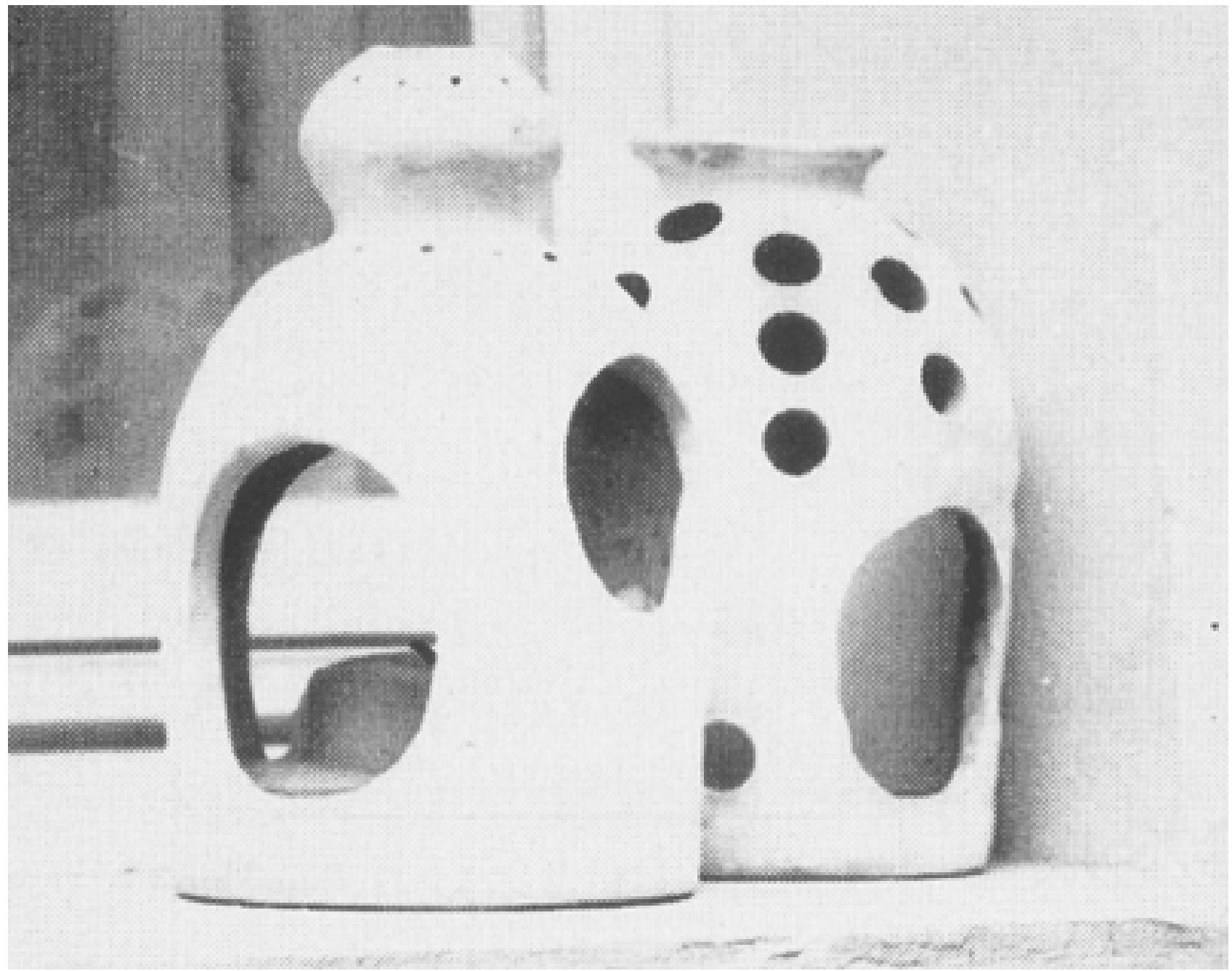
Both the retina and the thalamus function (approximately) as linear transducers

However, there is substantial connectivity and nonlinear processing within the cortex



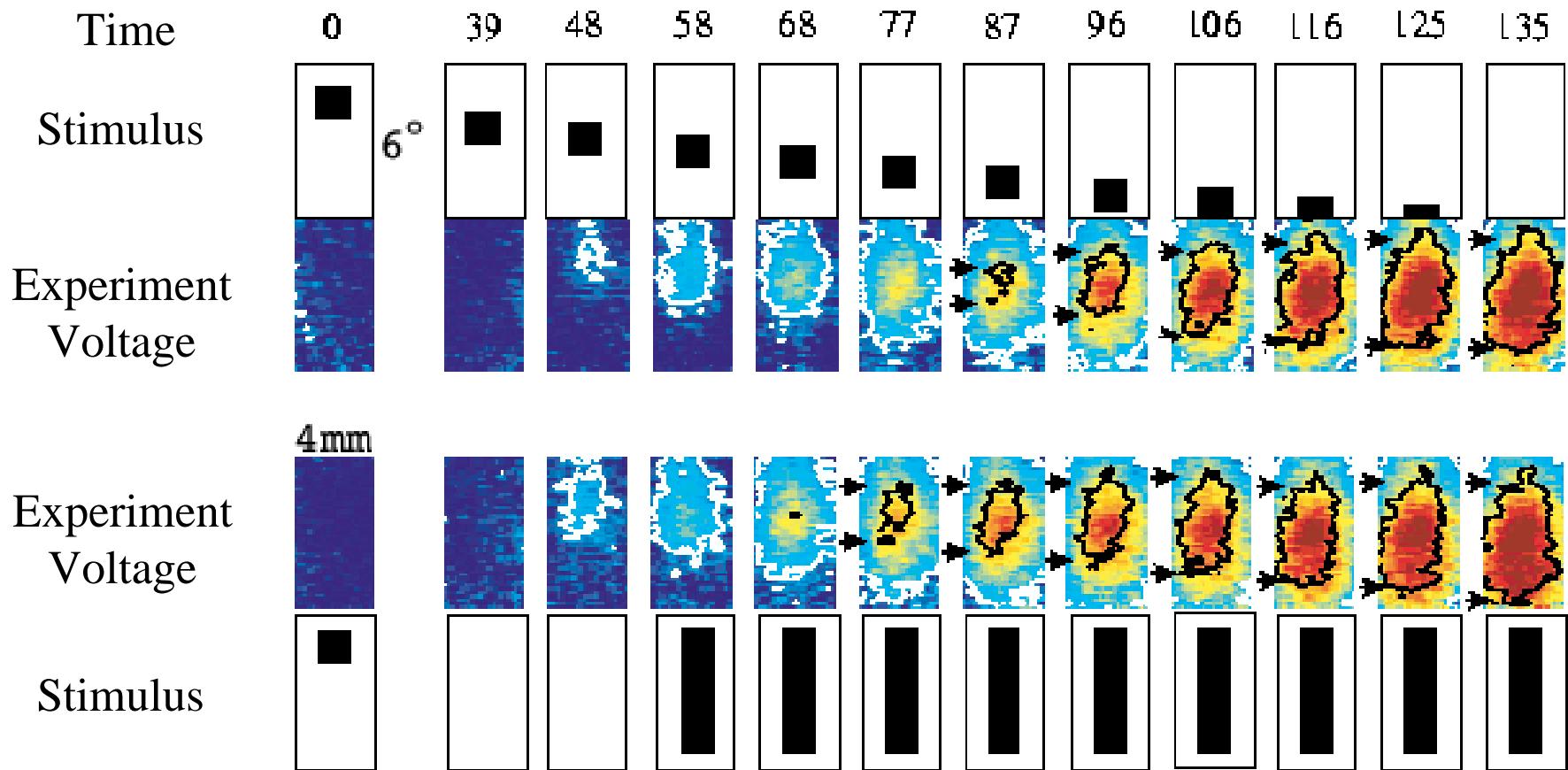






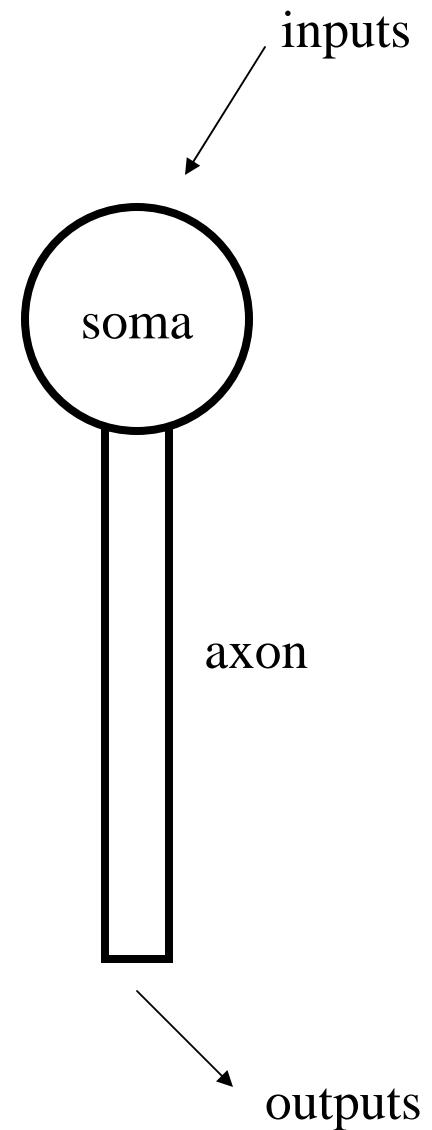
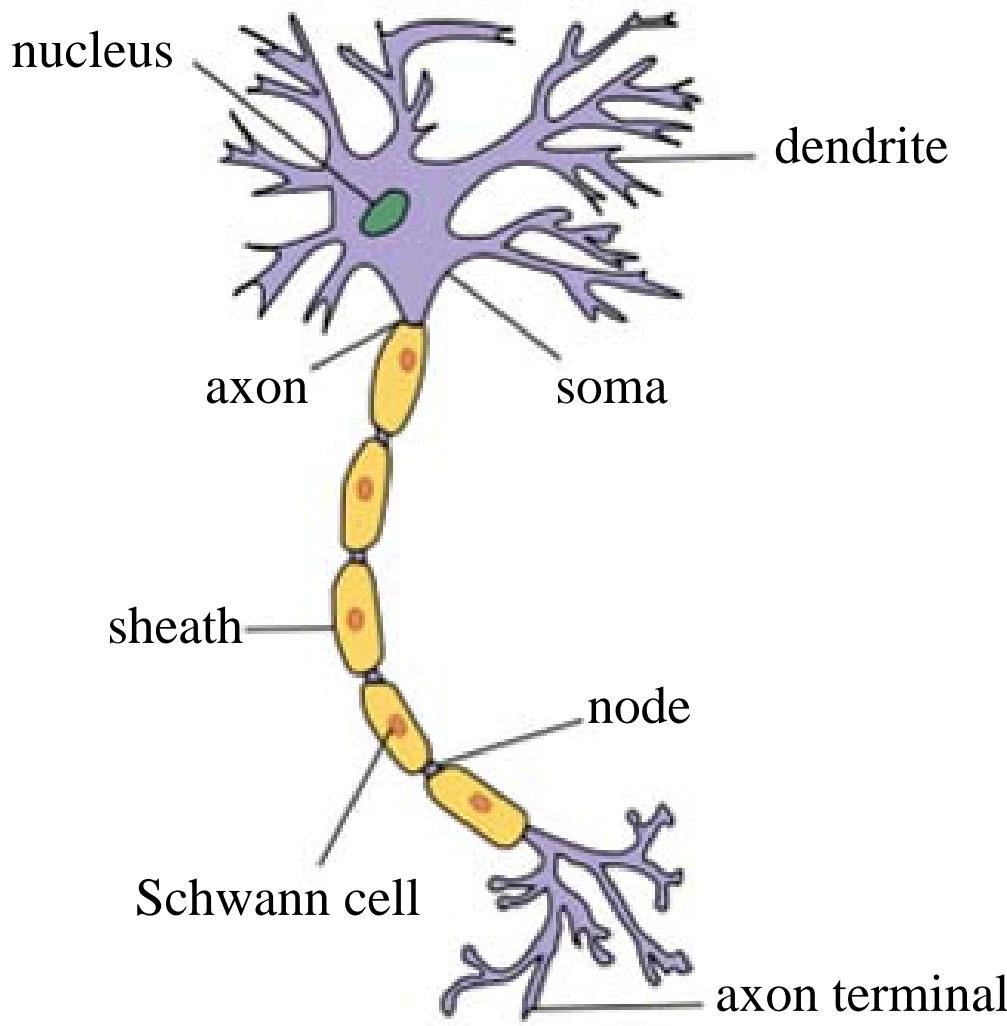
## Line-Motion Illusion

# Experiment — Line Motion Illusion



Grinvald et al.

**Brain = 1.5mTONS of neurons! (okay, 1.5 pounds)**



# Simple Neuronal Model – Integrate and Fire

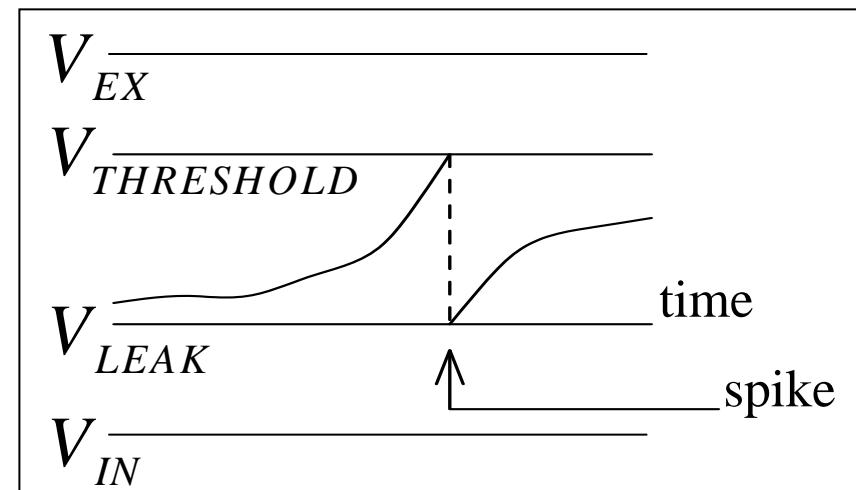
$$\partial_t V(t) = -G_{LEAK}(V - V_{LEAK}) - G^{EX}(V - V_{EX})$$

Nonlinear! Pulse Coupled

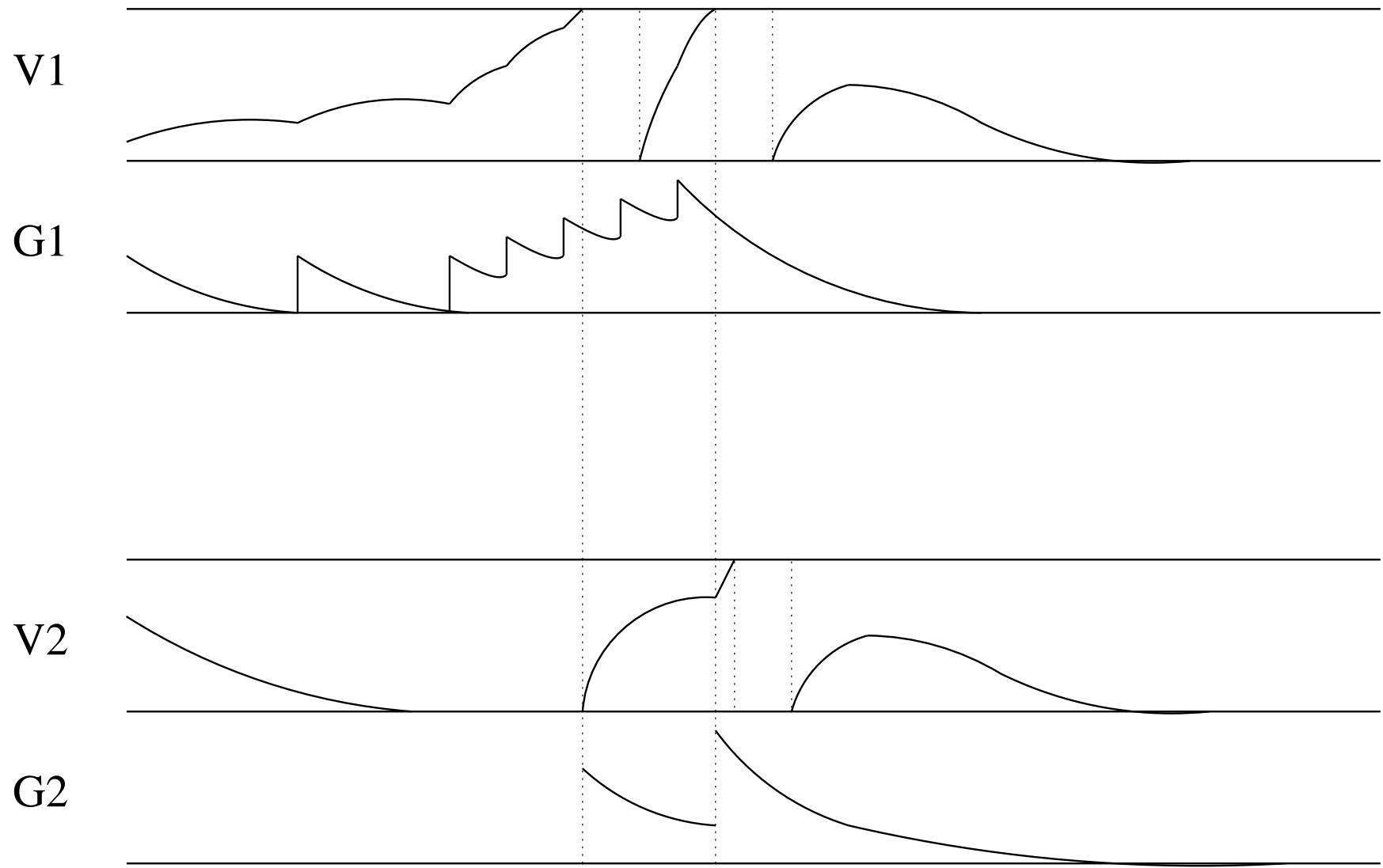
$V > V_{THRESHOLD} \rightarrow$  spike at  $T^k$

$$\partial_t G^{EX}(t) = -\frac{1}{\tau_{EX}} G^{EX}(t) + \sum_k \delta(t - T_{\text{input}}^k)$$

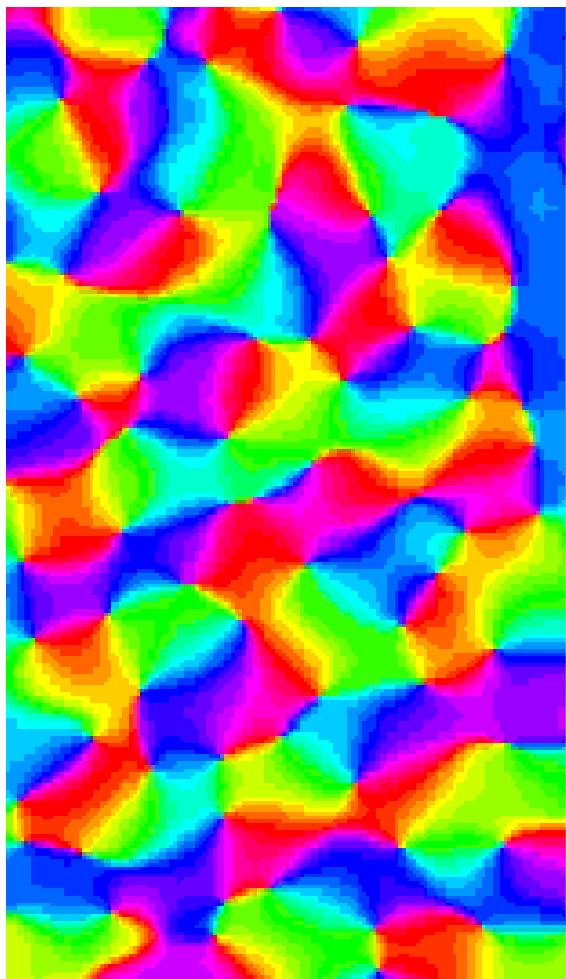
$$\alpha^{EX}(t) = \mu [e^{-t/\tau_{EX}}]$$



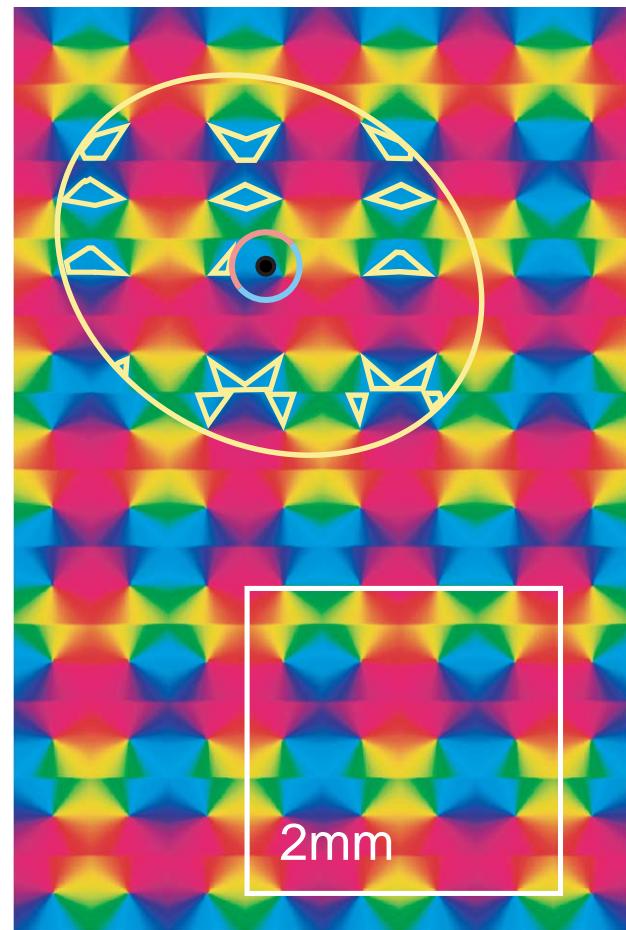
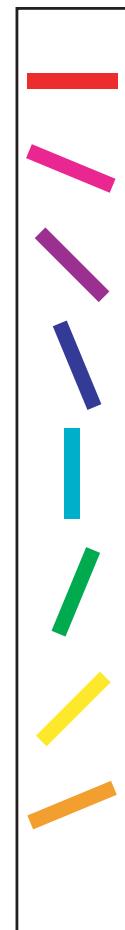
# Simple Neuronal Model – Integrate and Fire



# Actual Cortex ~25mm<sup>2</sup>



# Model Cortex



# Reasonable Neuronal Model – Integrate and Fire (3 conductance types)

$$\partial_t V_i(x_i, t) = -G_{LEAK}(V_i - V_{LEAK}) - G_i^{GABA}(V_i - V_{IN}) - G_i^{AMPA}(V_i - V_{EX}) - G_i^{NMDA}(V_i - V_{EX})$$

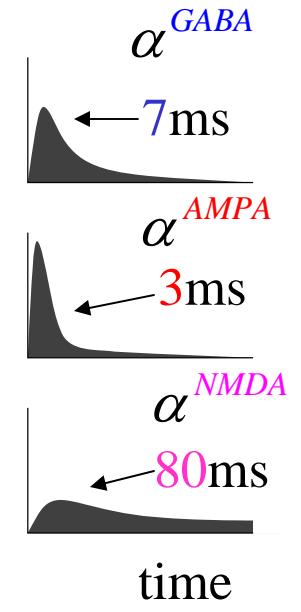
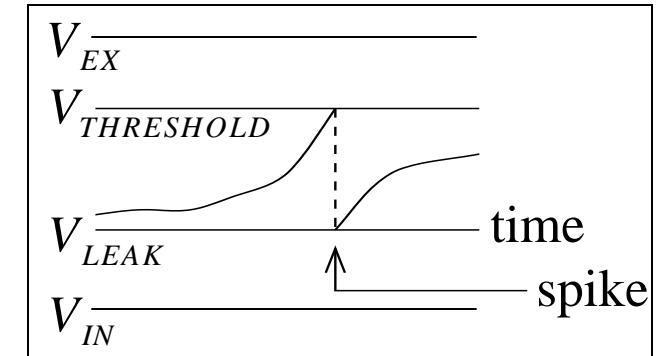
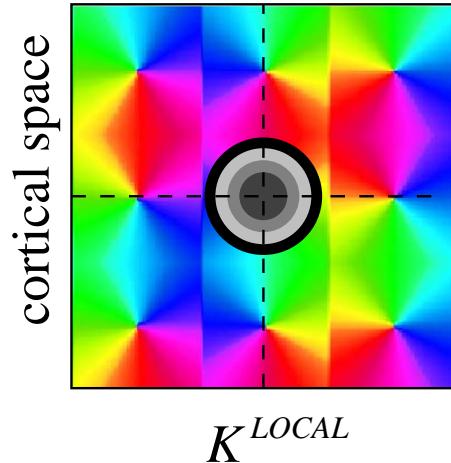
Nonlinear! Pulse Coupled

$$V_i > V_{THRESHOLD} \rightarrow \text{spike at } T_i^k$$

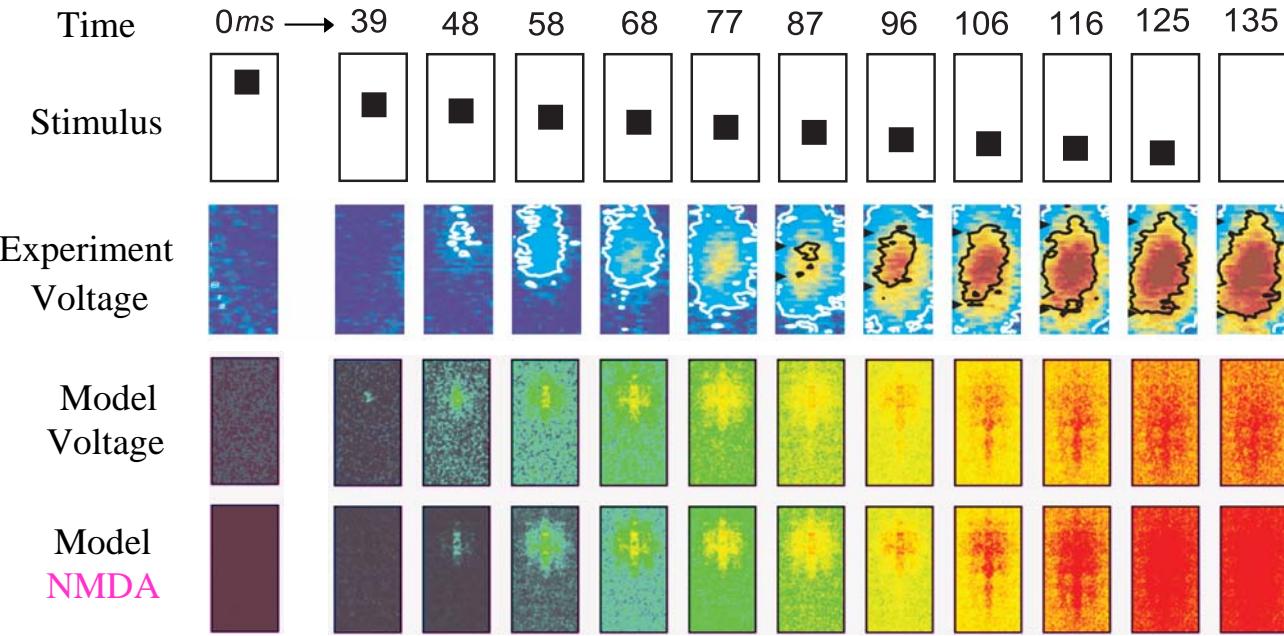
$$\partial_t G_i^{GABA}(x_i, t) = S^{GABA} \sum_{j \in \{\text{Inhibitory}\}} K_{x_i, x_j}^{LOCAL} \sum_k \alpha^{GABA}(t - T_j^k)$$

$$\partial_t G_i^{AMPA}(x_i, t) = F_{x_i}^{LGN}(\text{Stimulus}) + S^{AMPA} \sum_{j \in \{\text{Excitatory}\}} K_{x_i, x_j}^{LOCAL} \sum_k \alpha^{AMPA}(t - T_j^k)$$

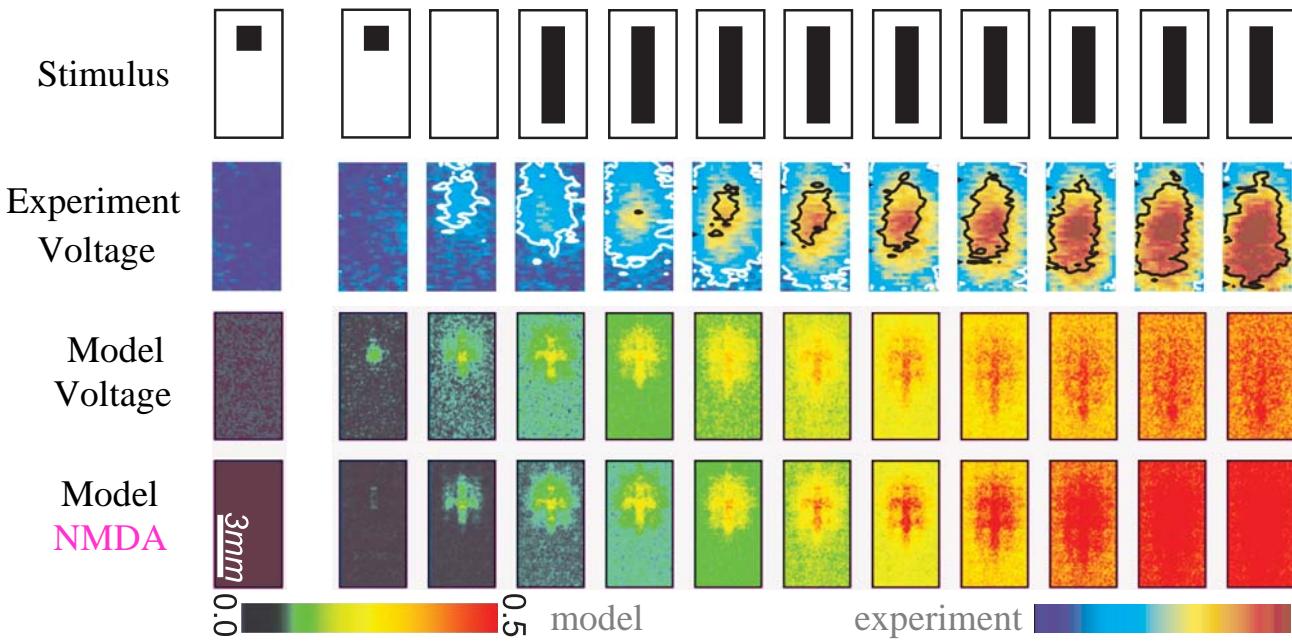
$$\partial_t G_i^{NMDA}(x_i, t) = S^{NMDA} \sum_{j \in \{\text{Excitatory}\}} K_{x_i, x_j}^{LONG-RANGE} \sum_k \alpha^{NMDA}(t - T_j^k)$$



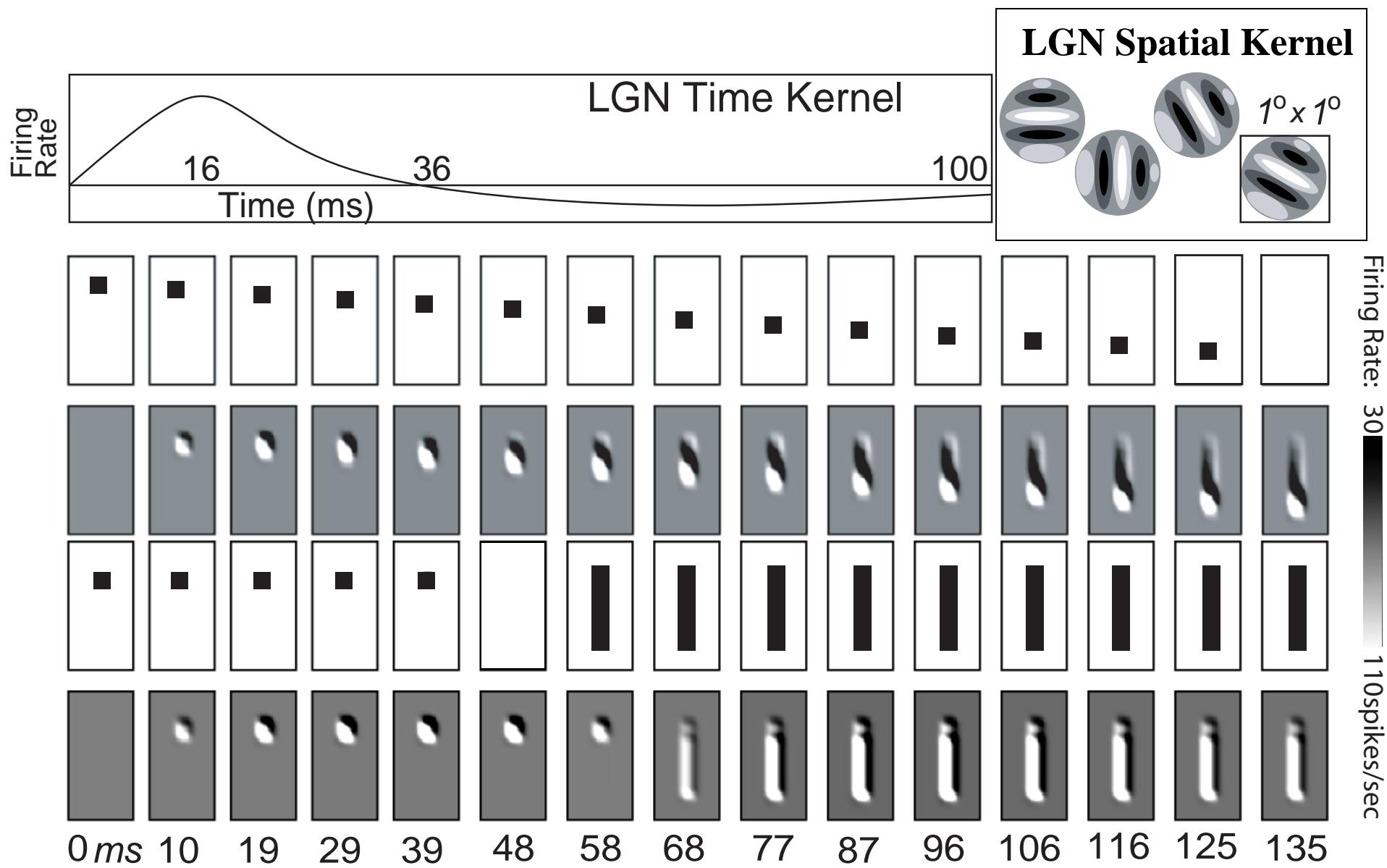
# Drifting Square Stimulus



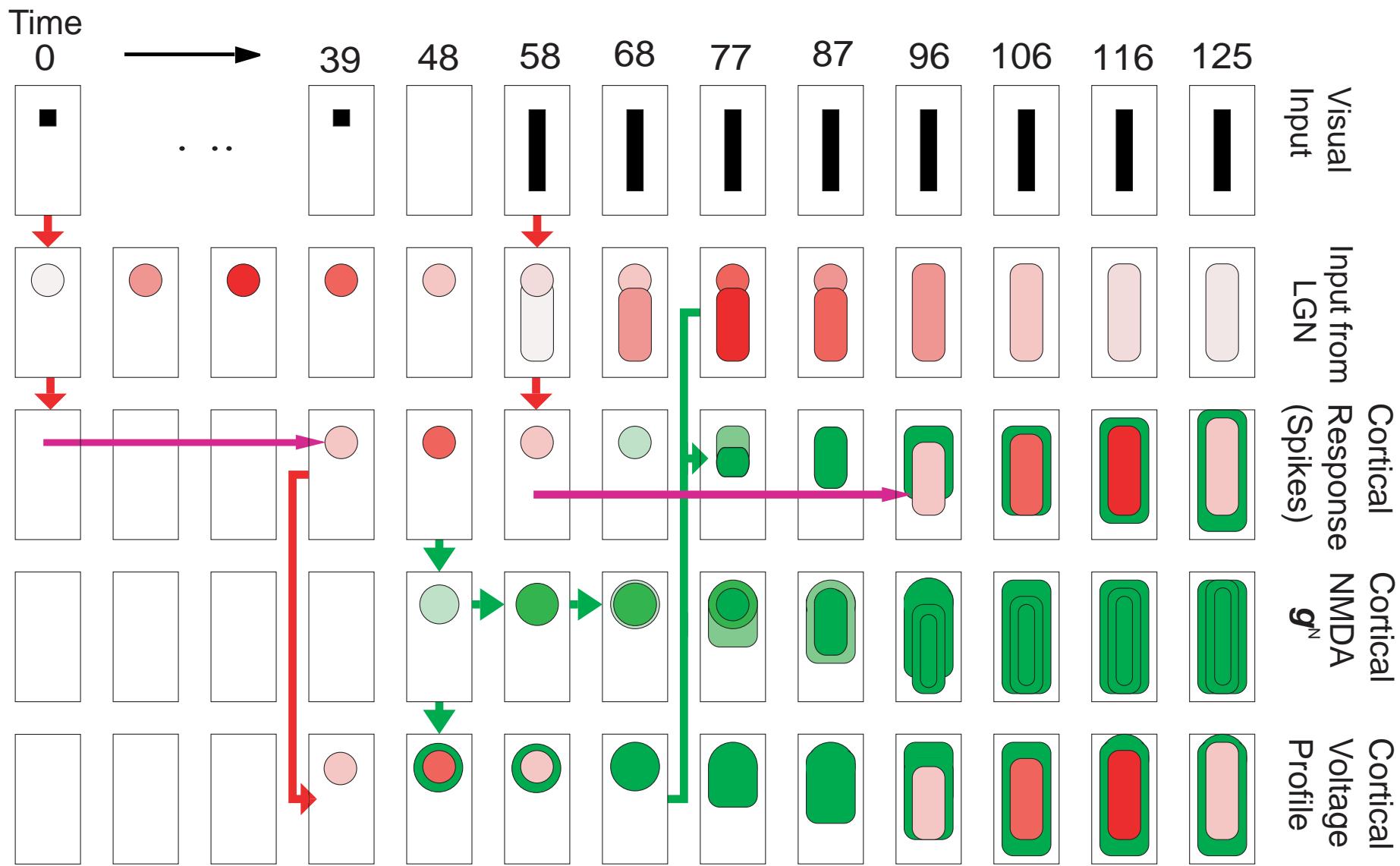
# Line Motion Illusion Stimulus



# Input? What does the Thalamus do?



# Mechanisms — Intermittently De-Suppressed system



## What is going on?

- Not a ‘wave’ of synaptic delays
- LGN time course + Cortical recruitment + Priming effect
- NMDA time-scale crucial

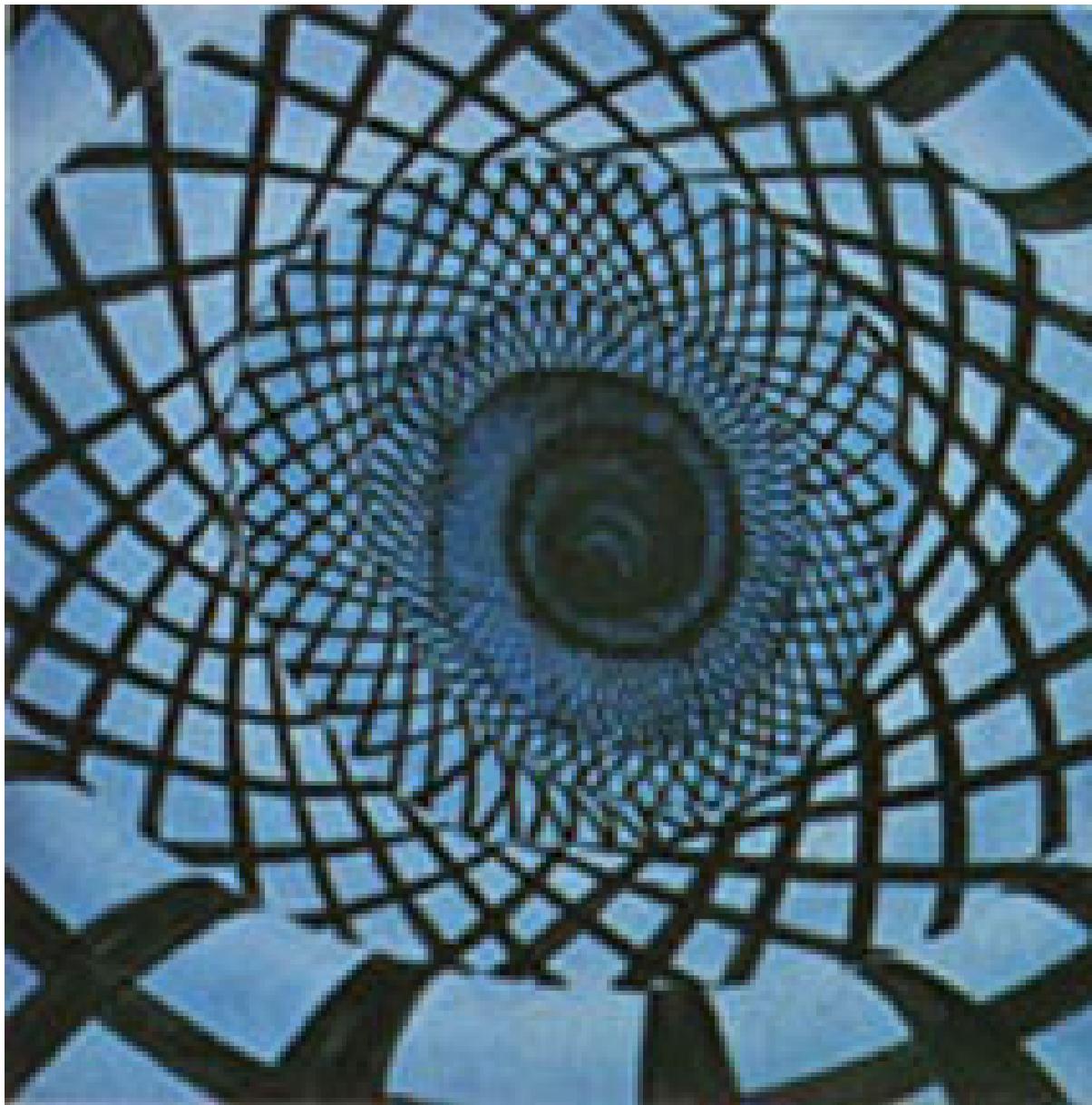
## Predictions:

- Not sensitive to Sharp Edges
- Not sensitive to Linearity of Bar
- Proximity matters
- Lower contrast delays recruitment

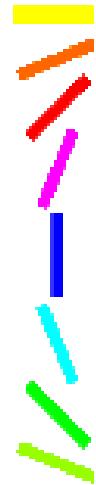
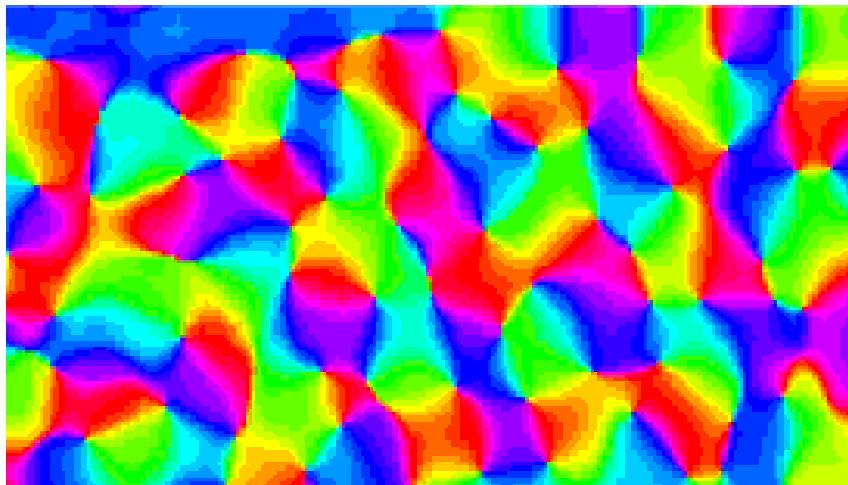
## Predicted line-motion-like variants



# Hallucinations induced by Lysergic acid diethylamide ?

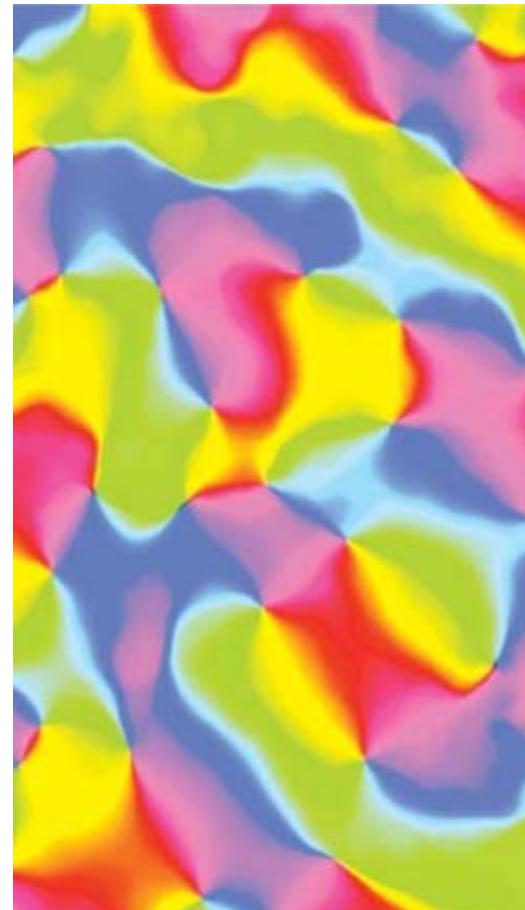


# Orientation Selectivity



Grinvald et al.

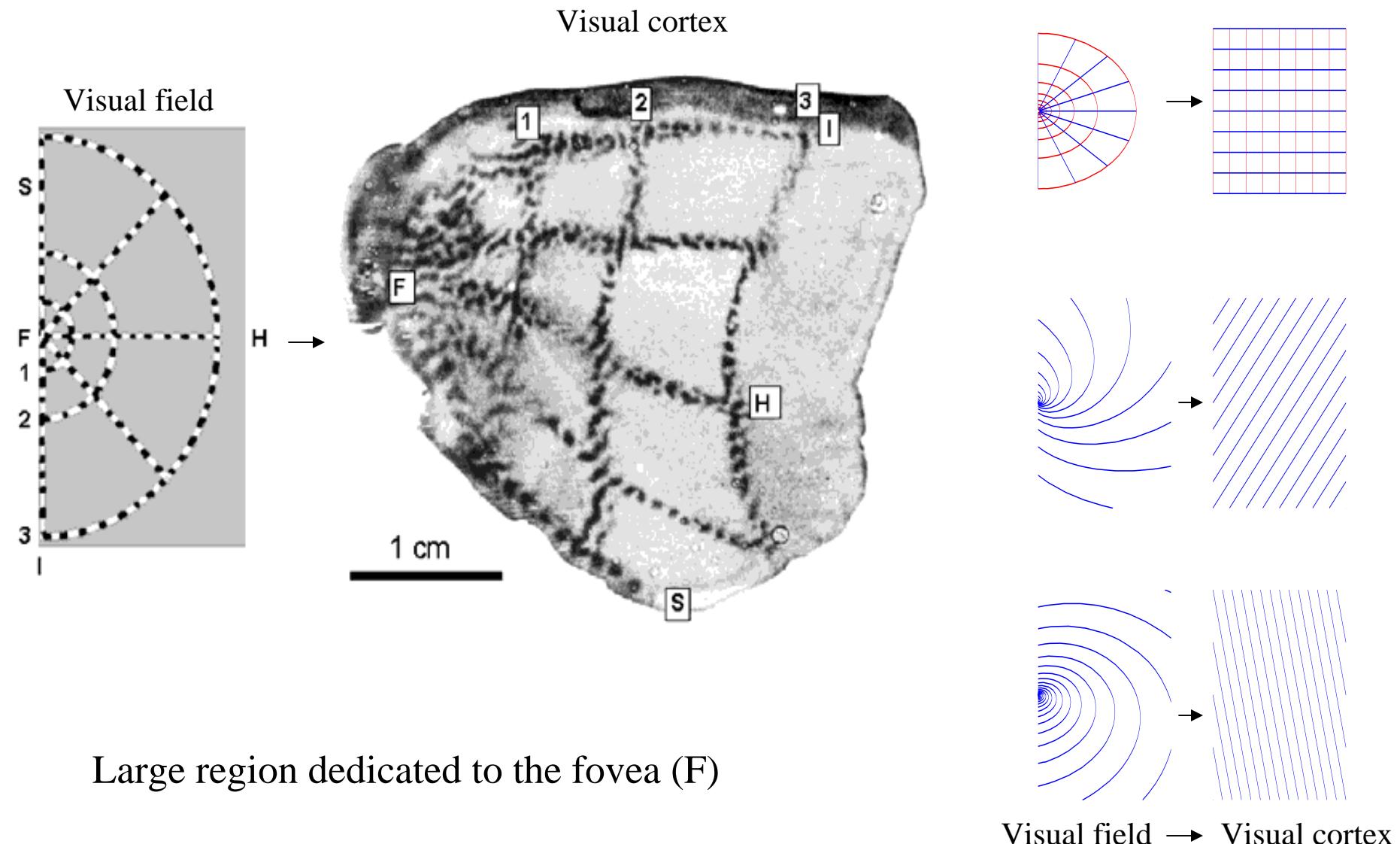
Orientation Domains  
approximately 0.5mm across



Sur et al.

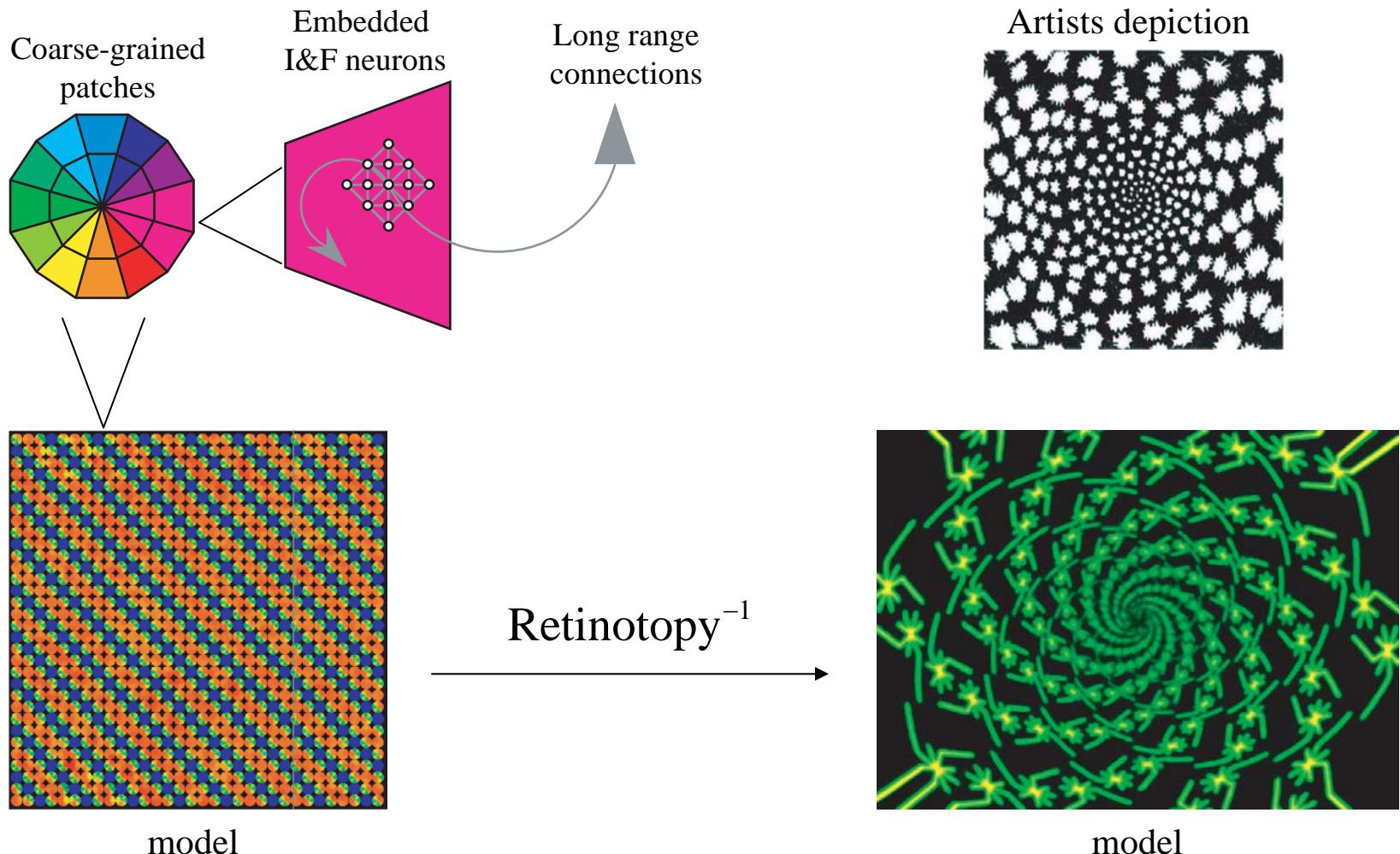
# Retinotopy: a map from retina to V1

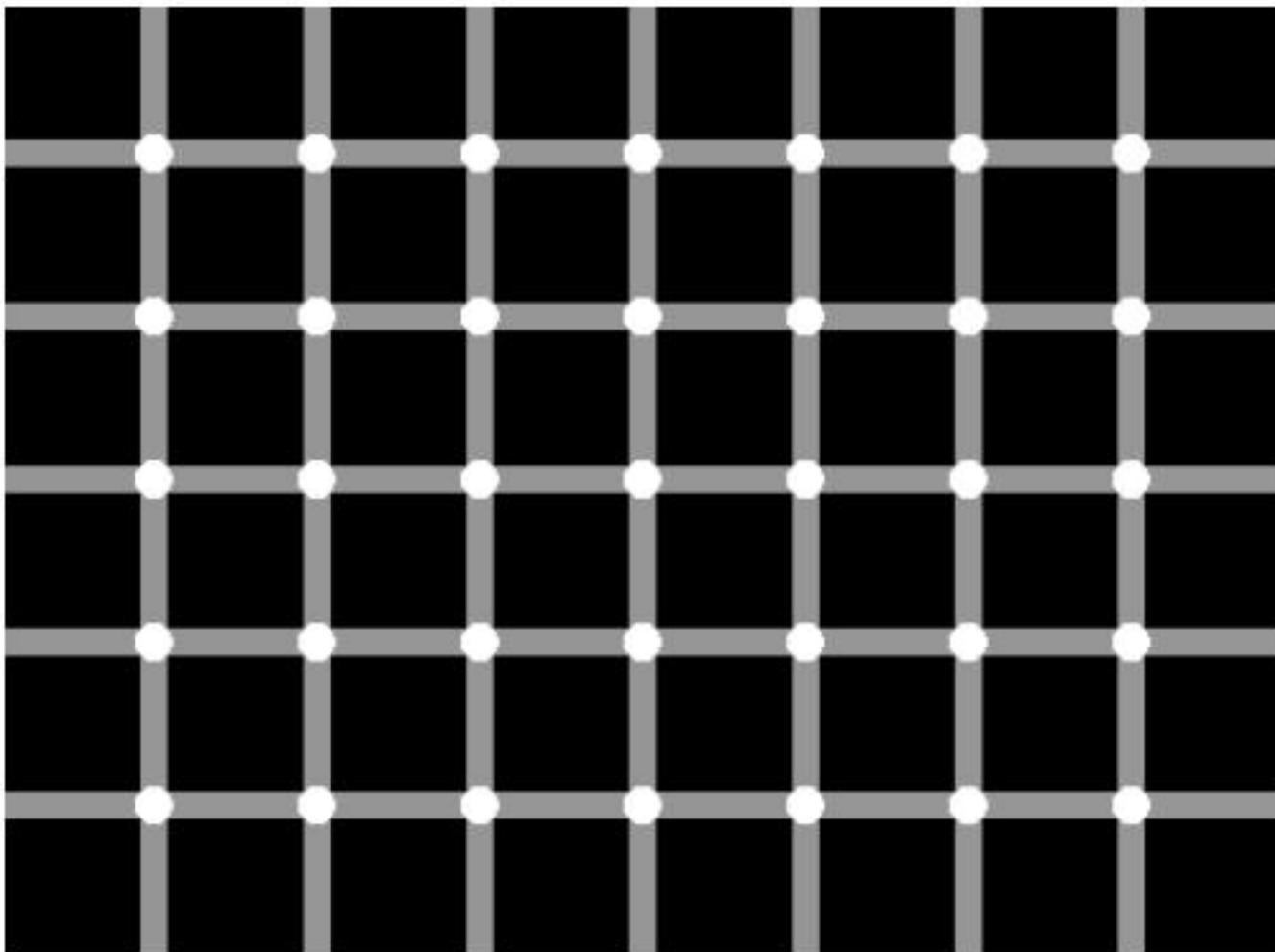
$$re^{i\theta} \rightarrow \log(r) + i\theta$$



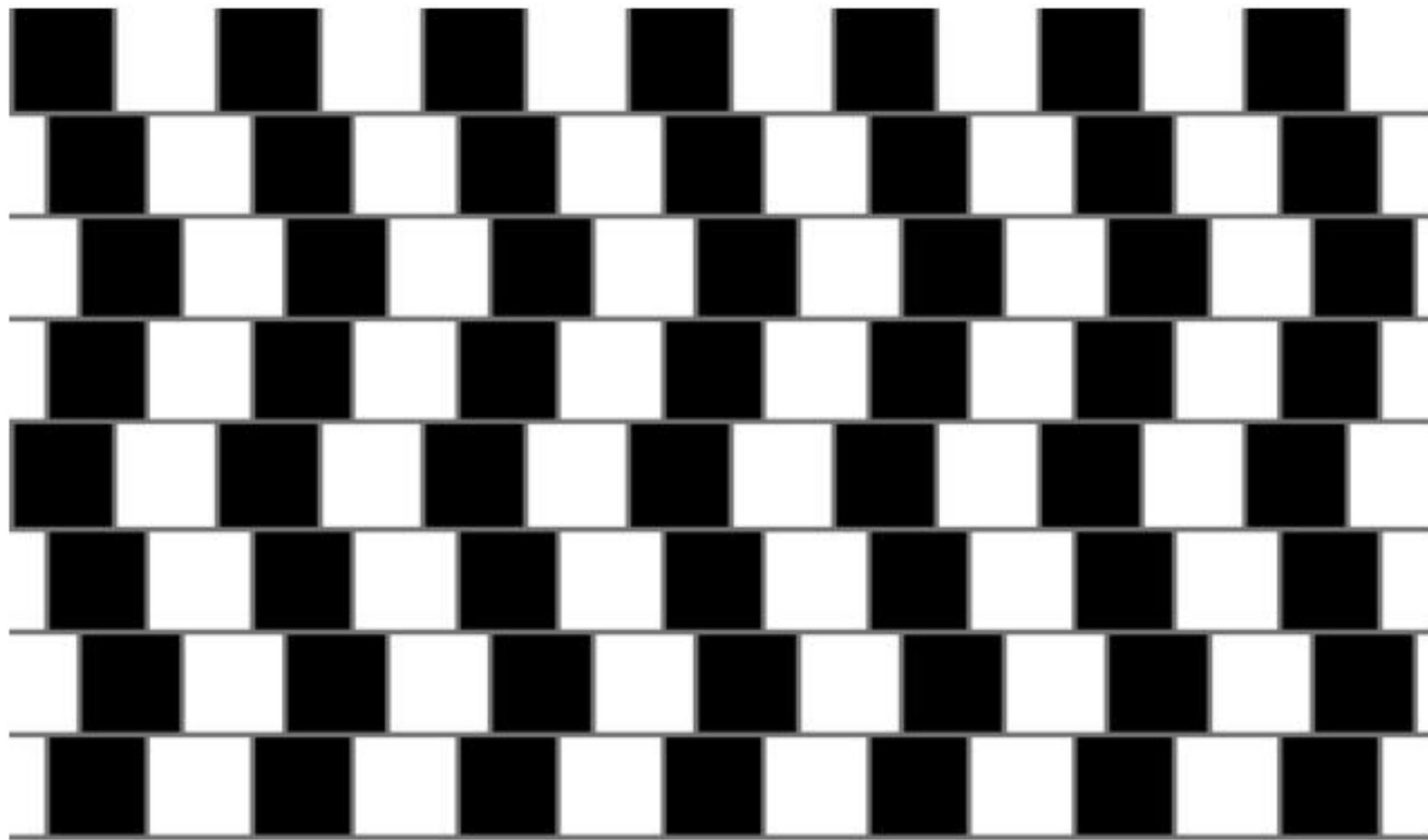
# Could cortical interconnectivity be responsible for spiral hallucinations?

(see Bressloff, Cowan et al.)

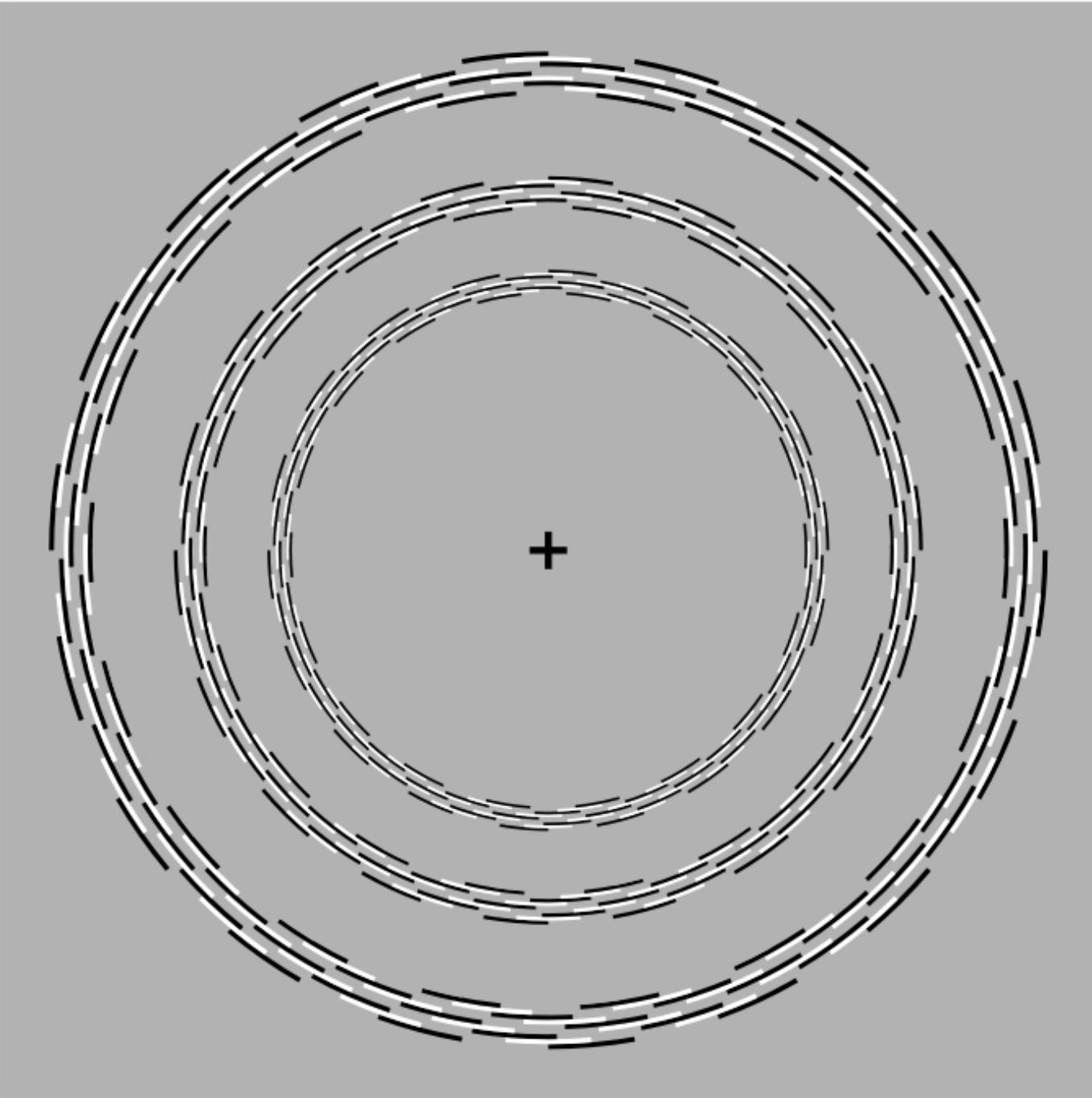


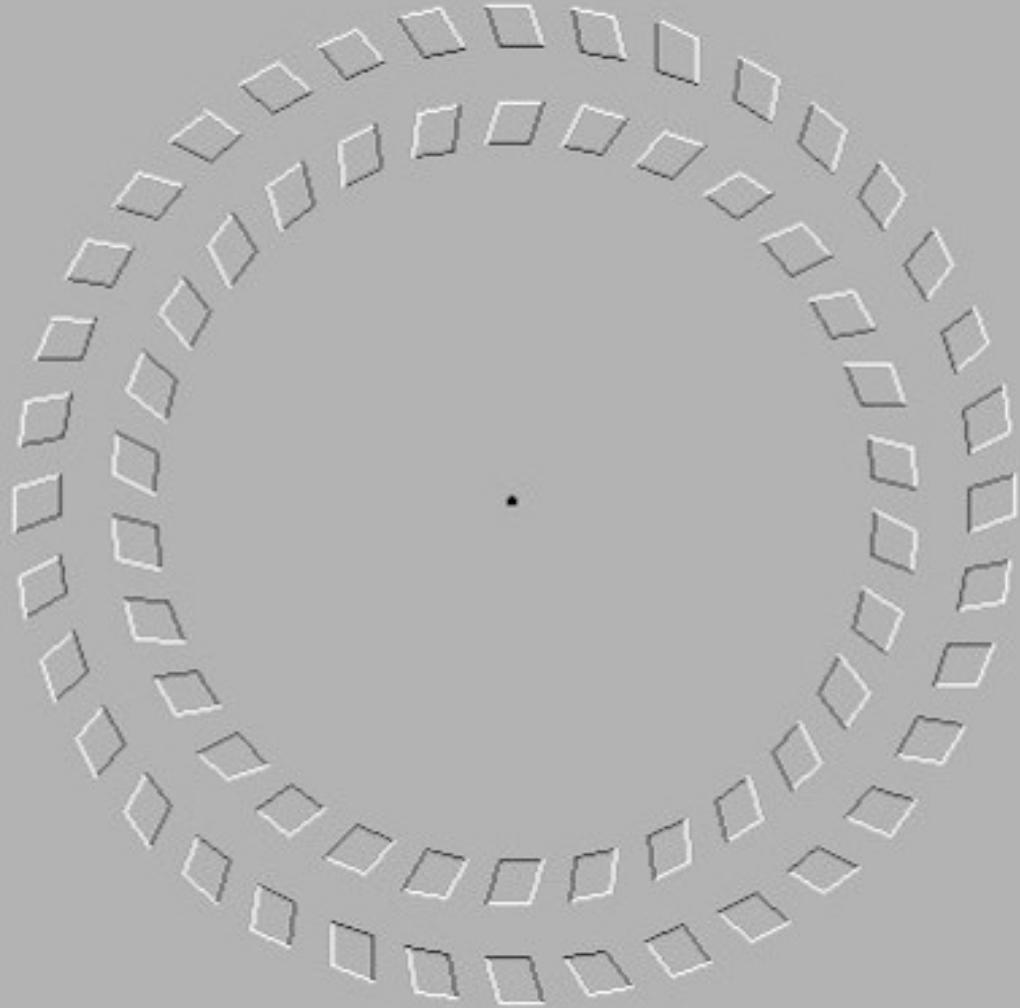


Count the black dots! :o)



Are the horizontal lines parallel or do they slope?





FOCUS ON THE DOT IN THE CENTRE AND MOVE YOU HEAD BACKWARDS AND FORWARDS.  
WEIRD HEY...

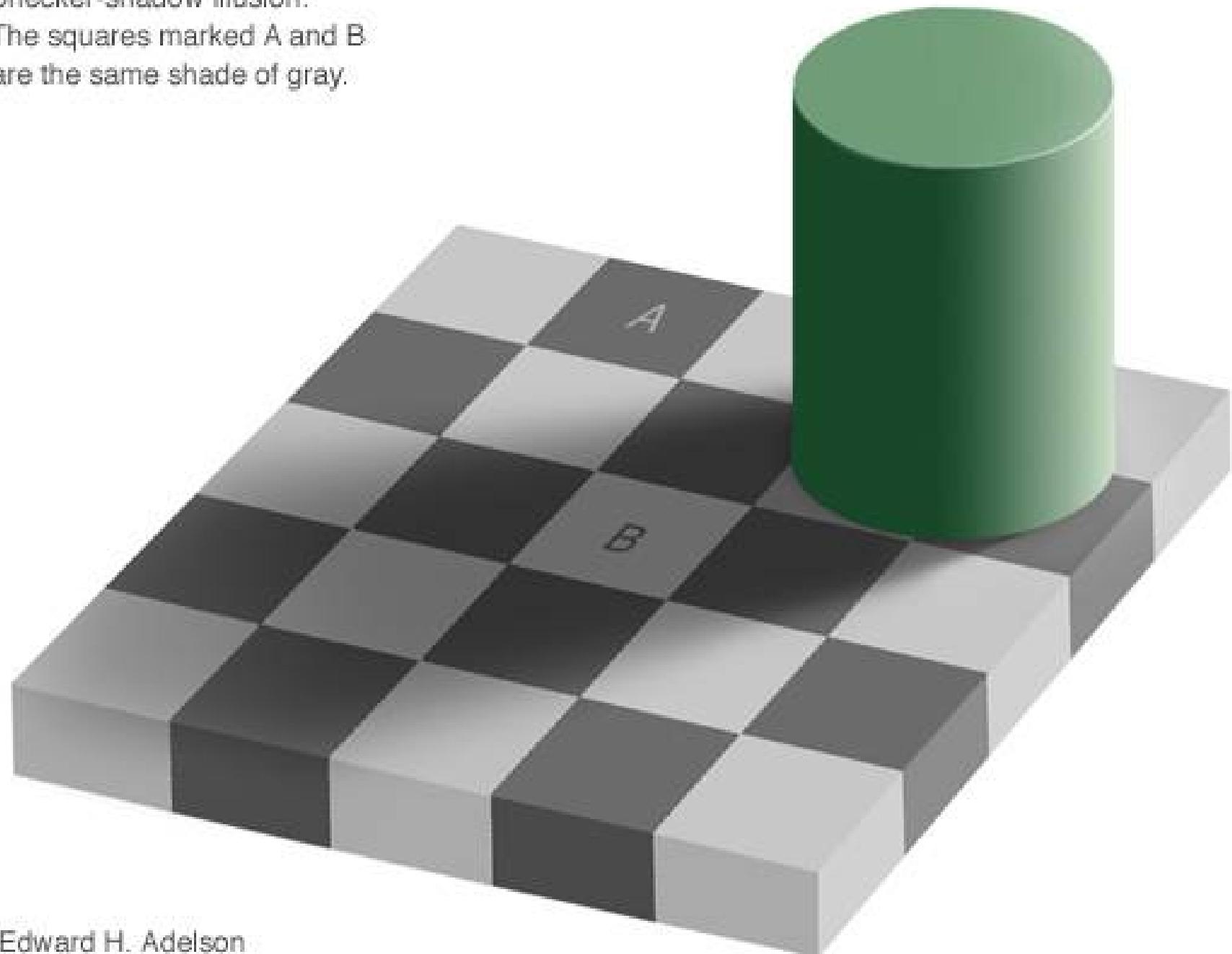
Linking a Neuronal response to visual input does NOT imply function!

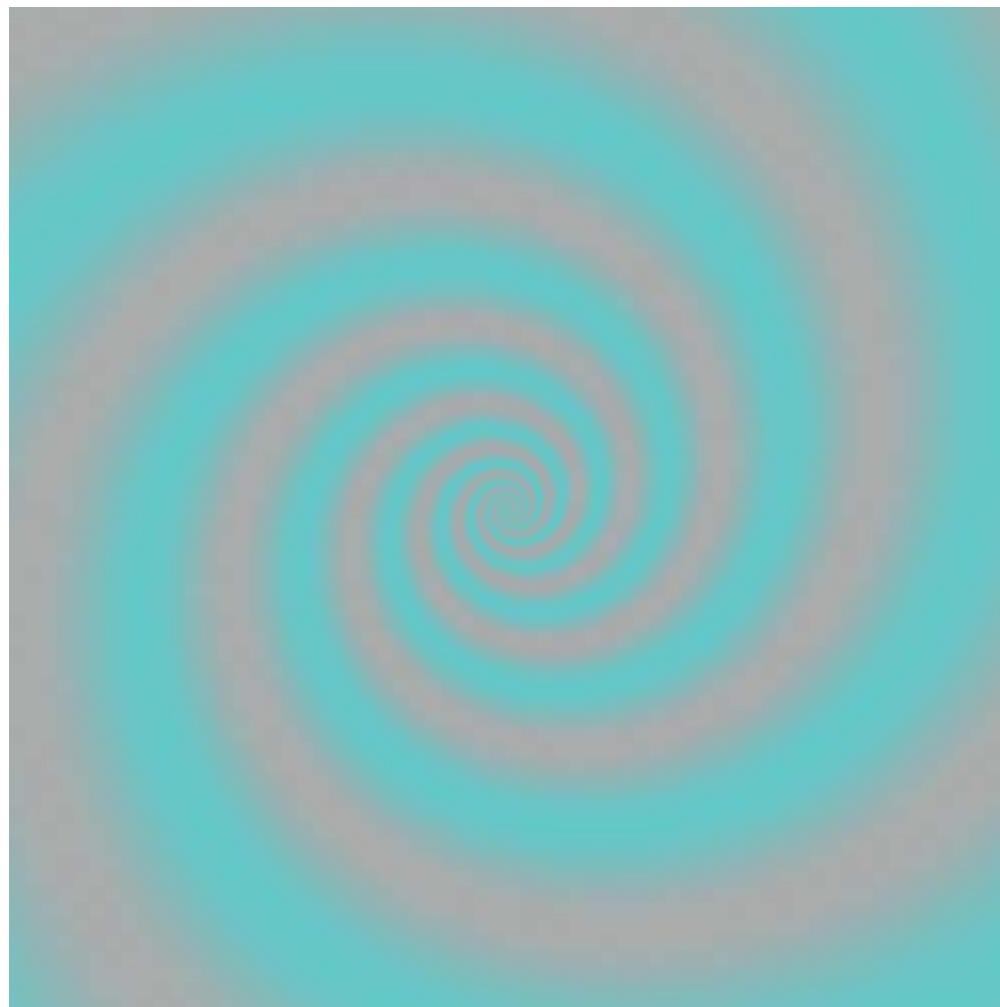




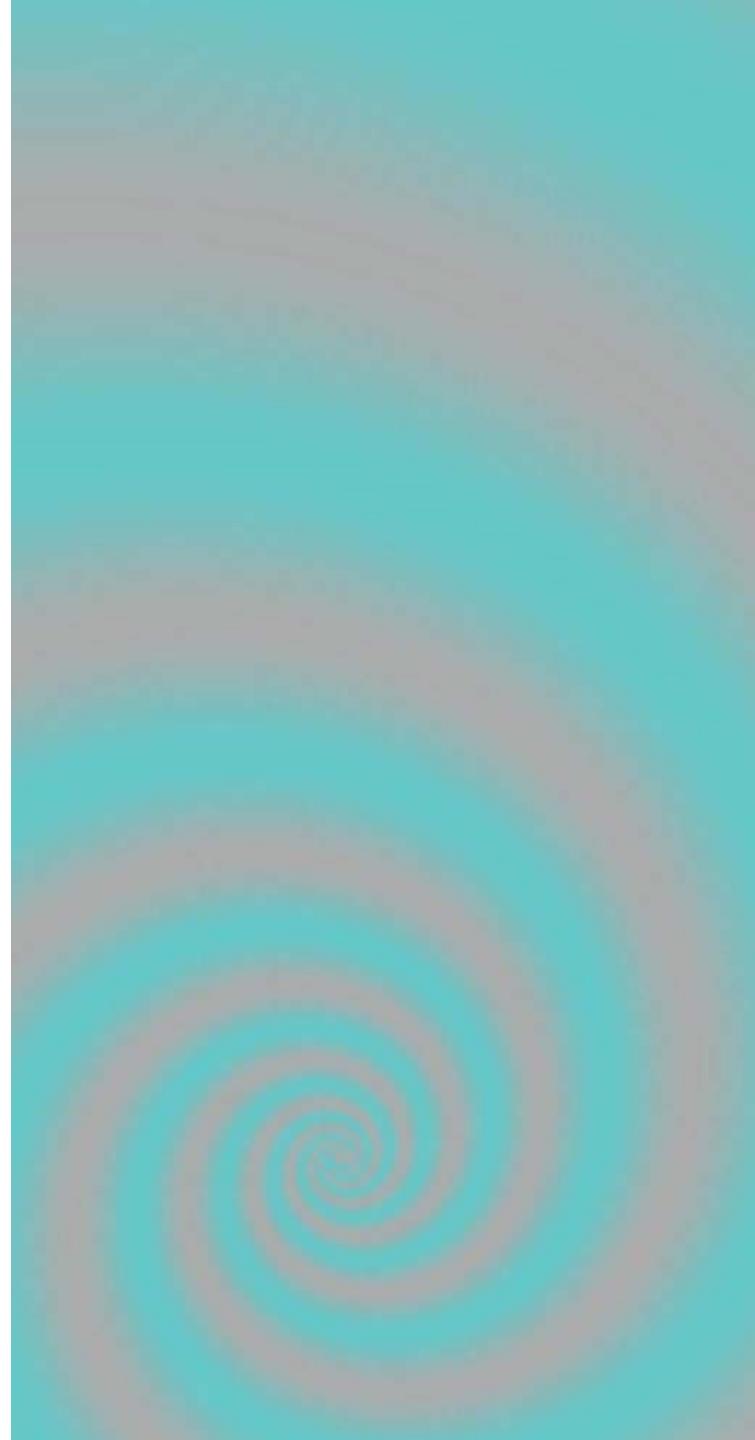
Checker-shadow illusion:

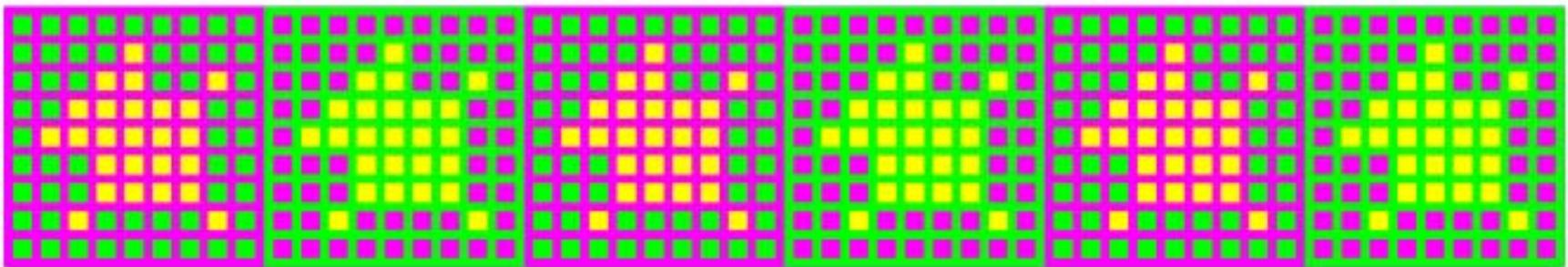
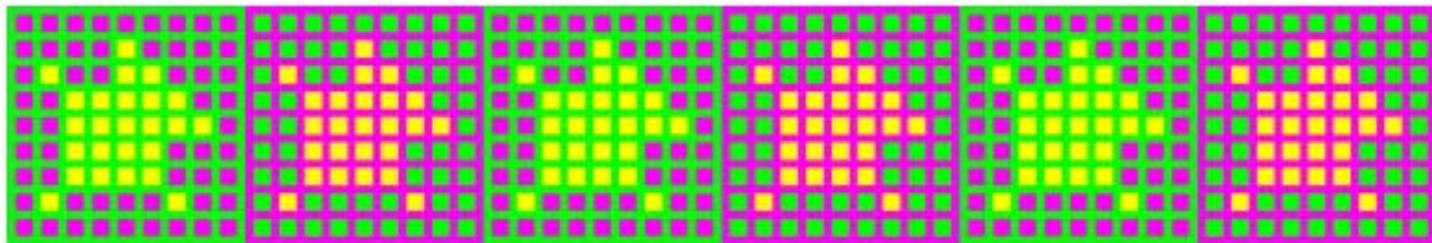
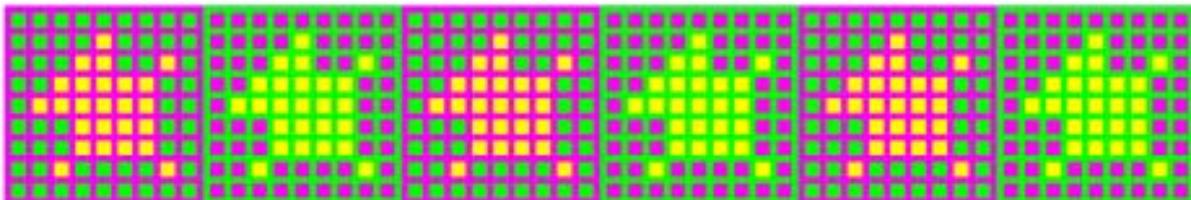
The squares marked A and B  
are the same shade of gray.

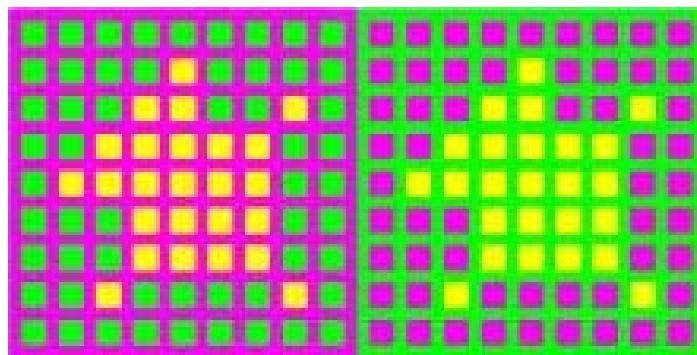


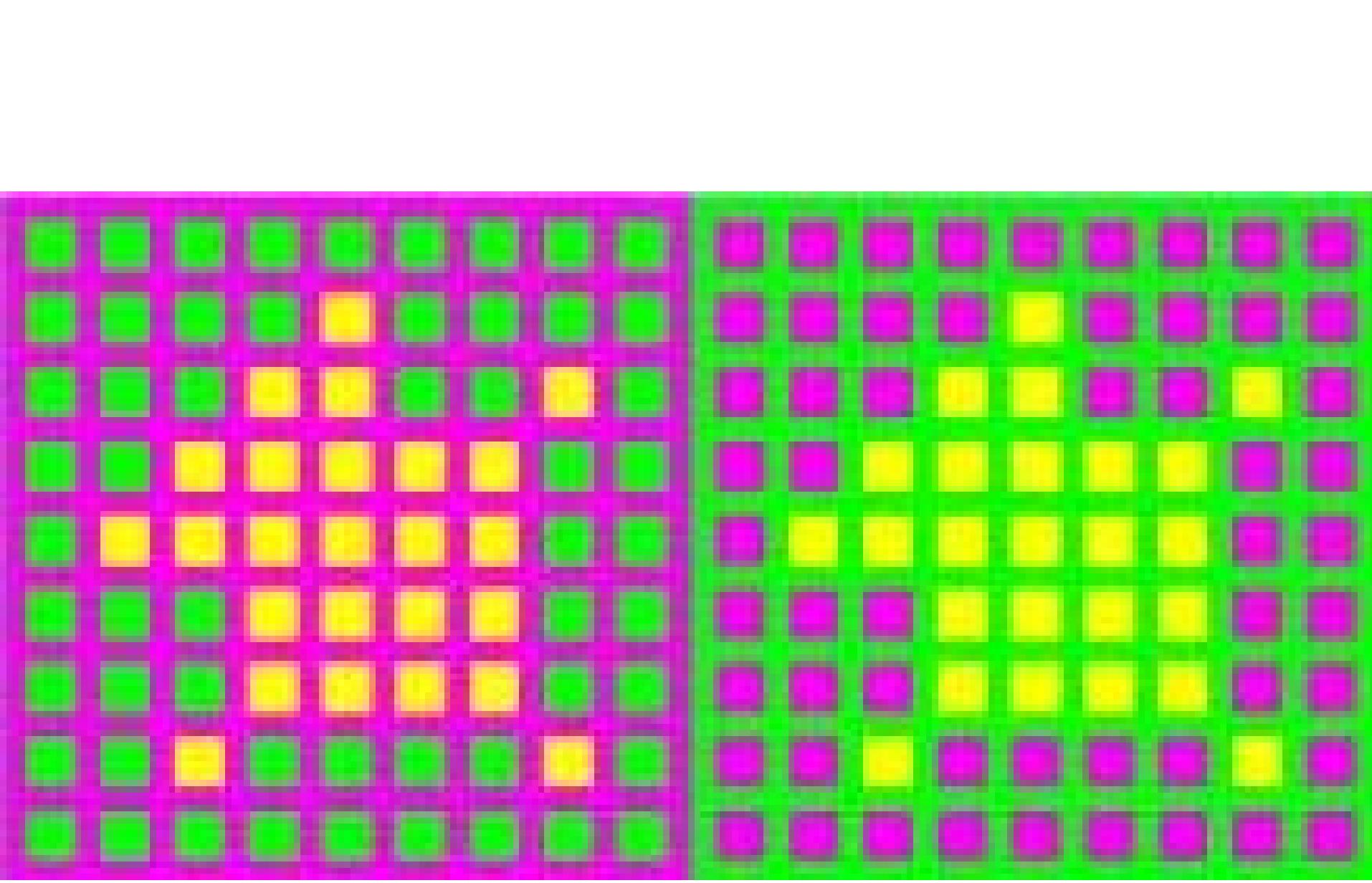


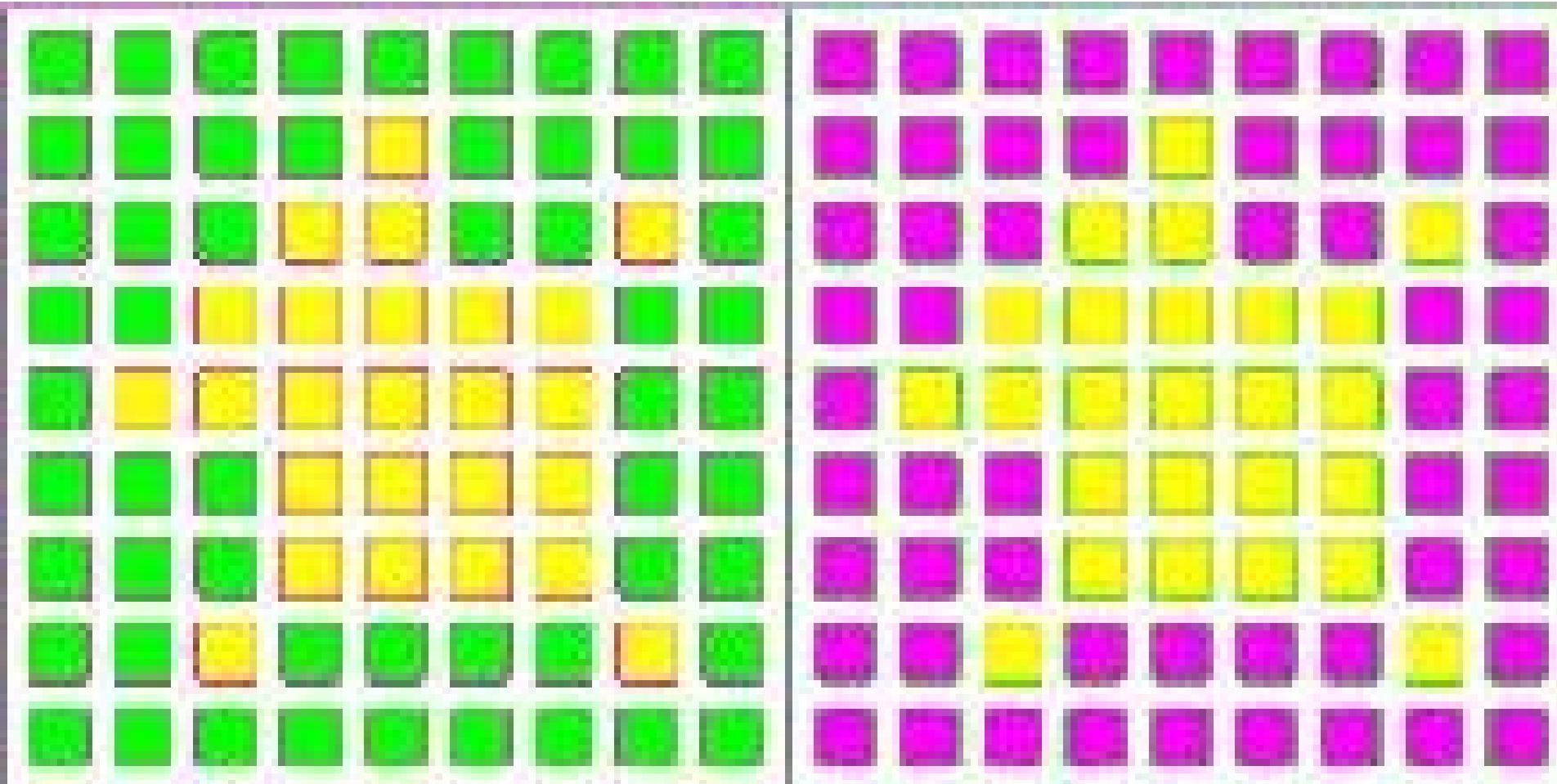


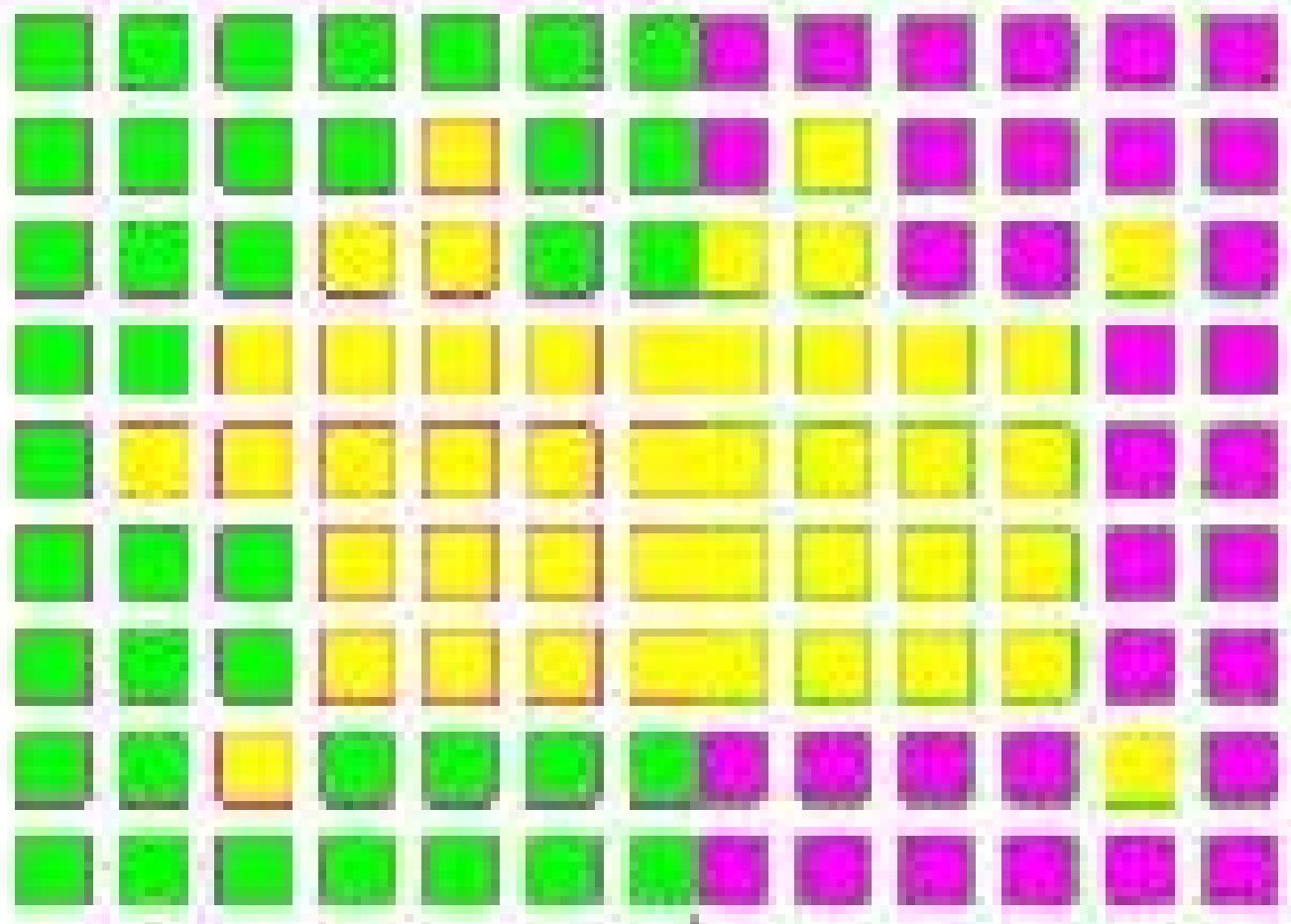


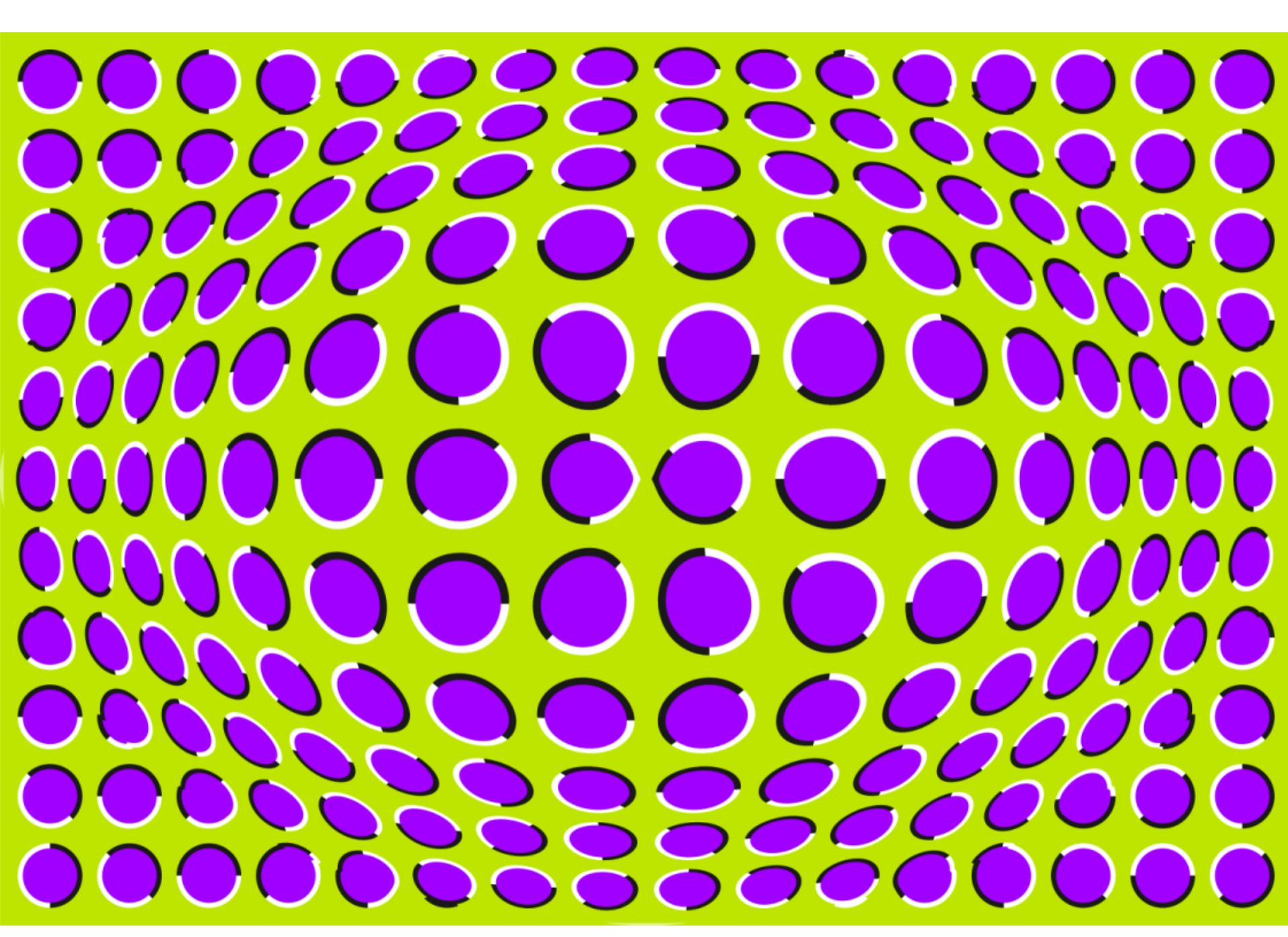


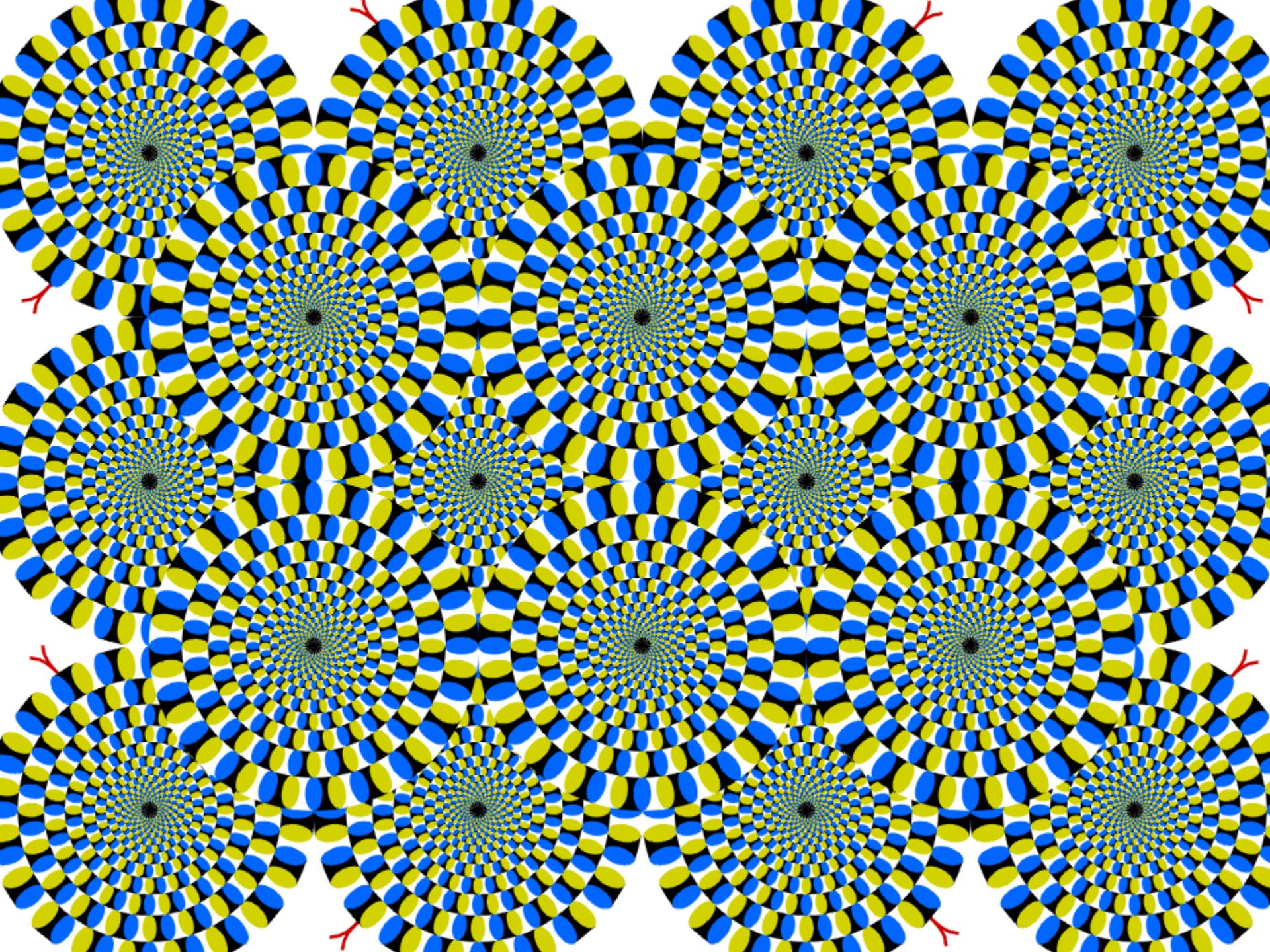


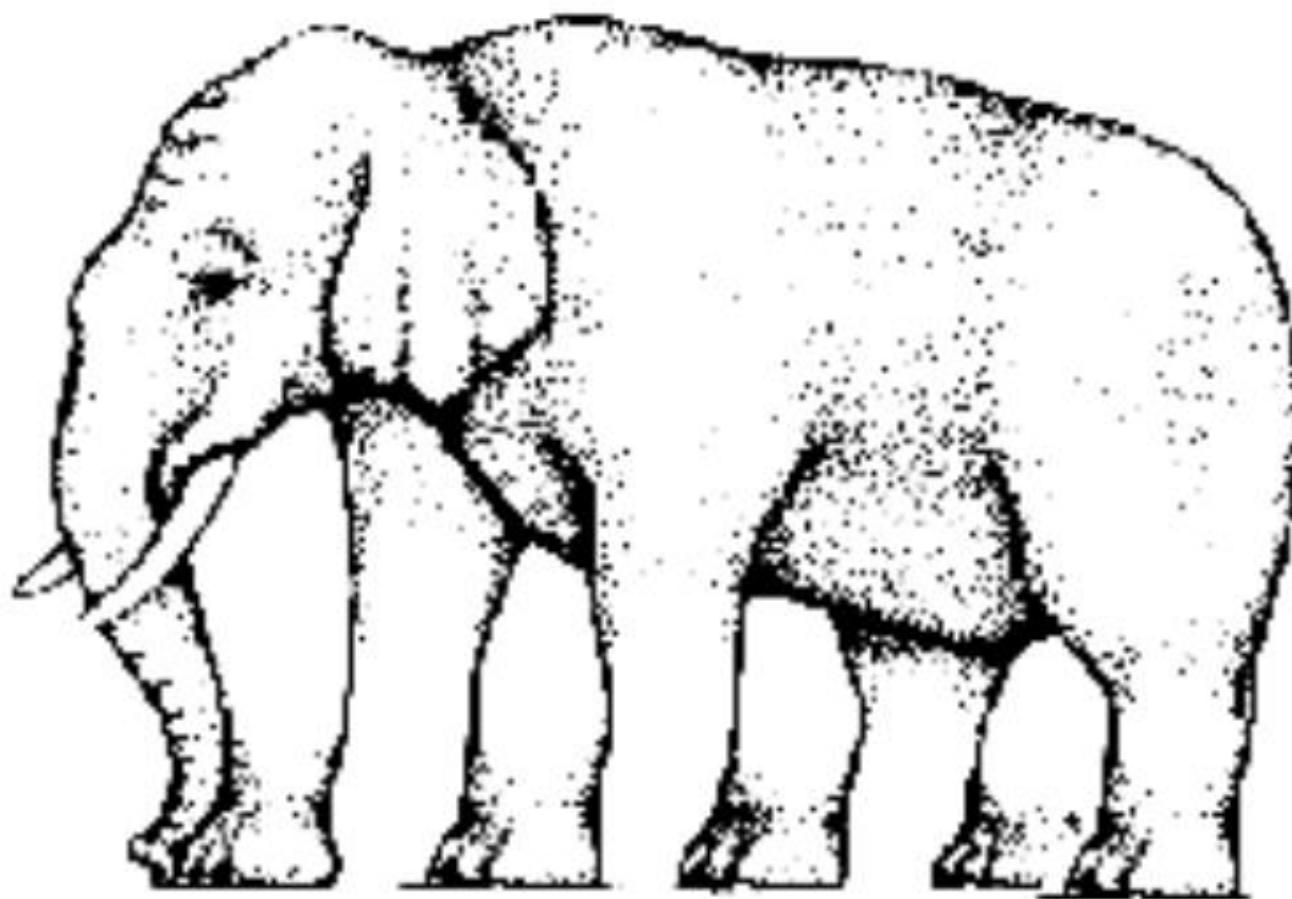












How many legs does this elephant have?

