# What Are All Those Neurons in Foveal V1 Doing?

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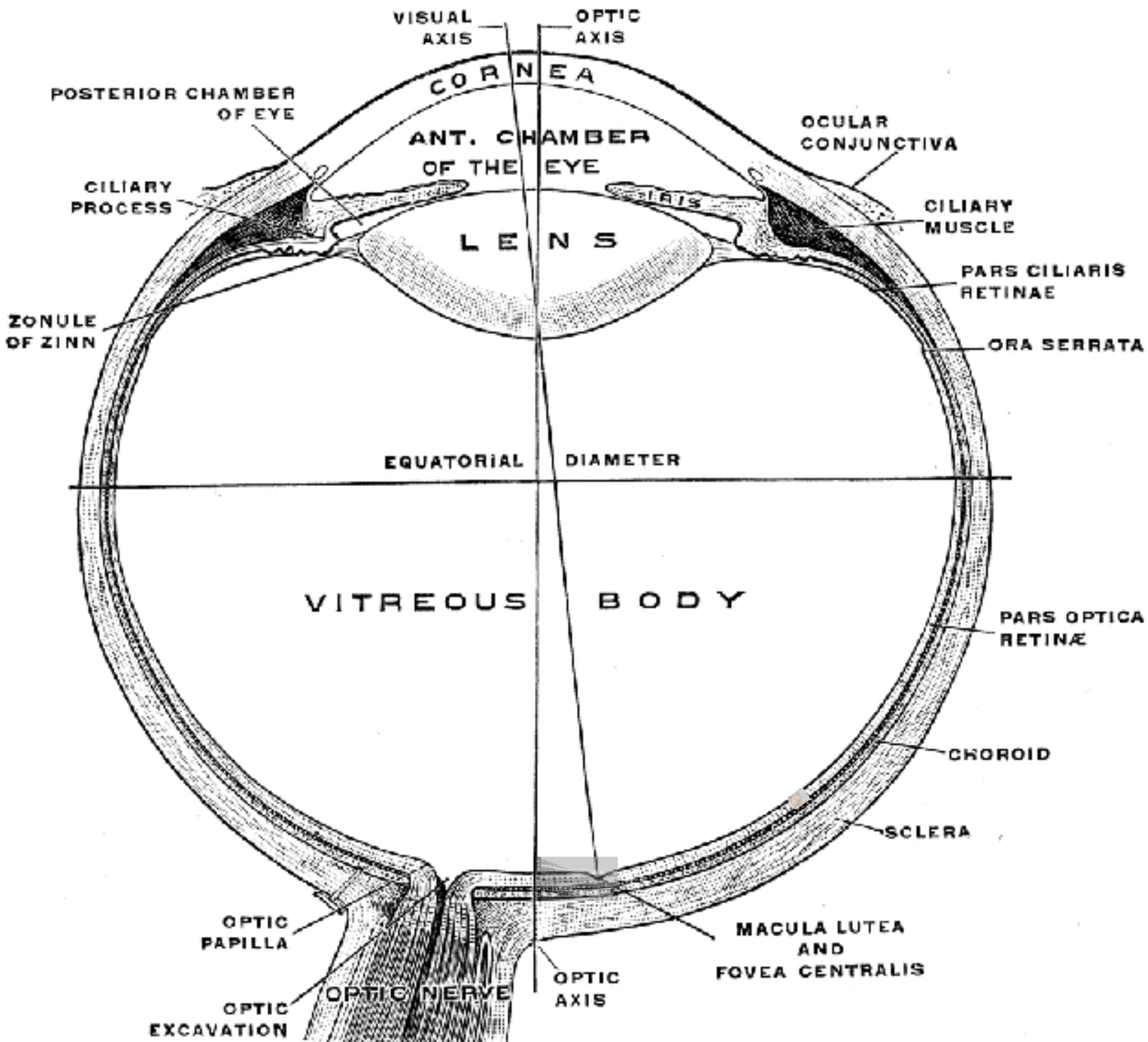
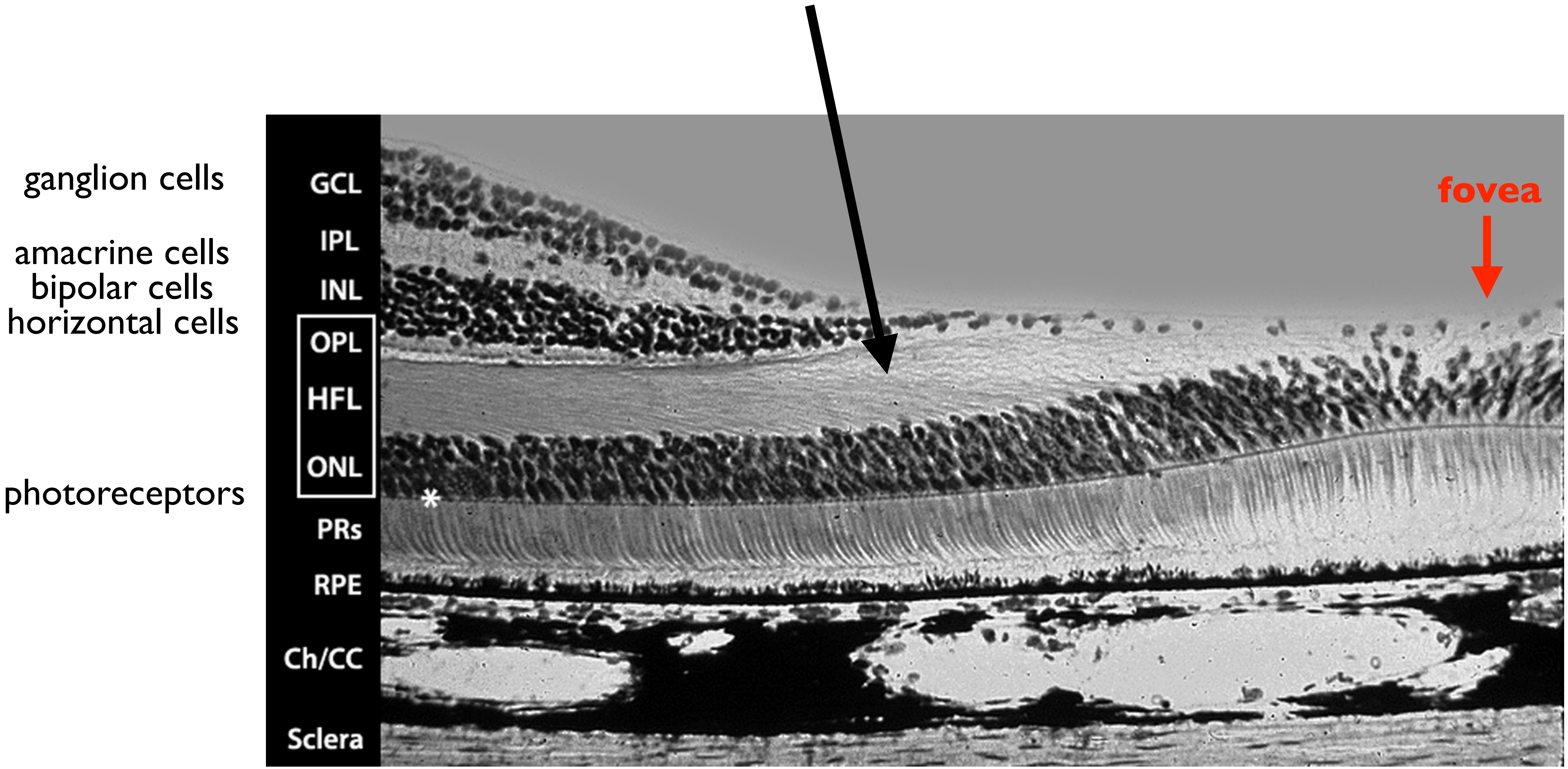
UC Berkeley

REDWOOD CENTER
for Theoretical Neuroscience

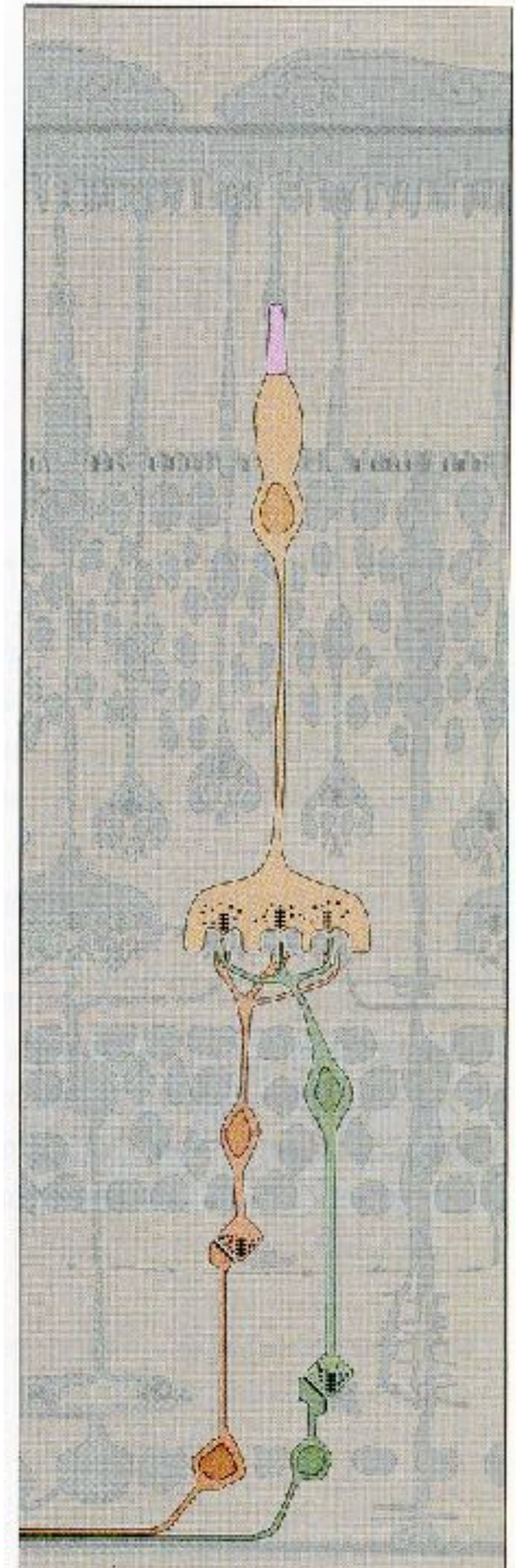

VISUAL AXIS
OPTIC AXIS
CORNEA
POSTERIOR CHAMBER OF EYE
ANT. CHAMBER OF THE EYE
OCULAR CONJUNCTIVA
CILIARY PROCESS
IRIS
CILIARY MUSCLE
LENS
PARS CILIARIS RETINAE
ZONULE OF ZINN
ORA SERRATA
EQUATORIAL DIAMETER
VITREOUS BODY
PARS OPTICA RETINÆ
CHOROID
SCLERA
OPTIC PAPILLA
MACULA LUTEA AND FOVEA CENTRALIS
OPTIC NERVE
OPTIC AXIS
OPTIC EXCAVATION

# Fibers of Henle



Midget ganglion cells receive input from midget bipolar cells.

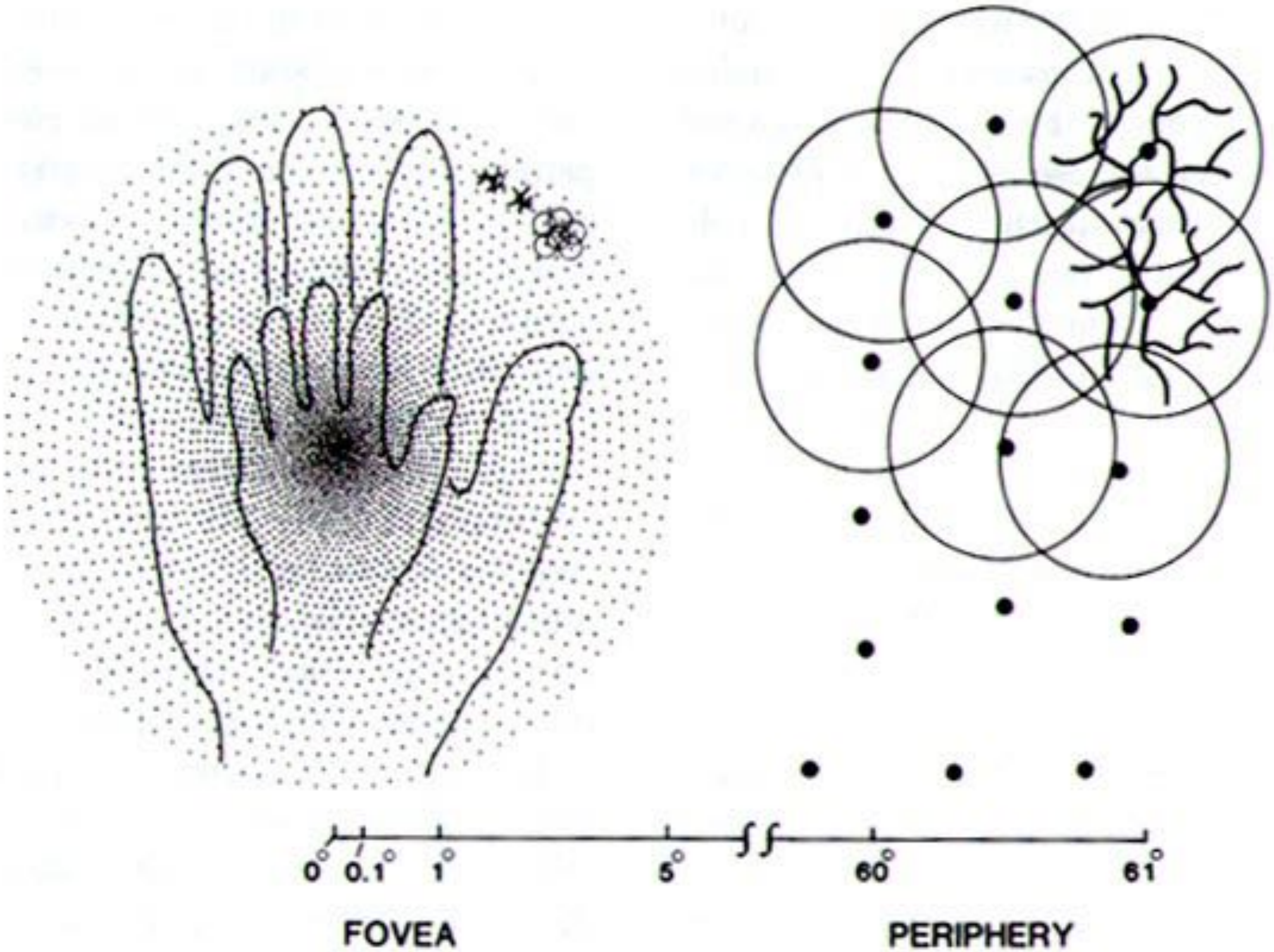
Ratio is 1:1 in fovea.



off- and on-midget pathways

# Retinal ganglion cell sampling array

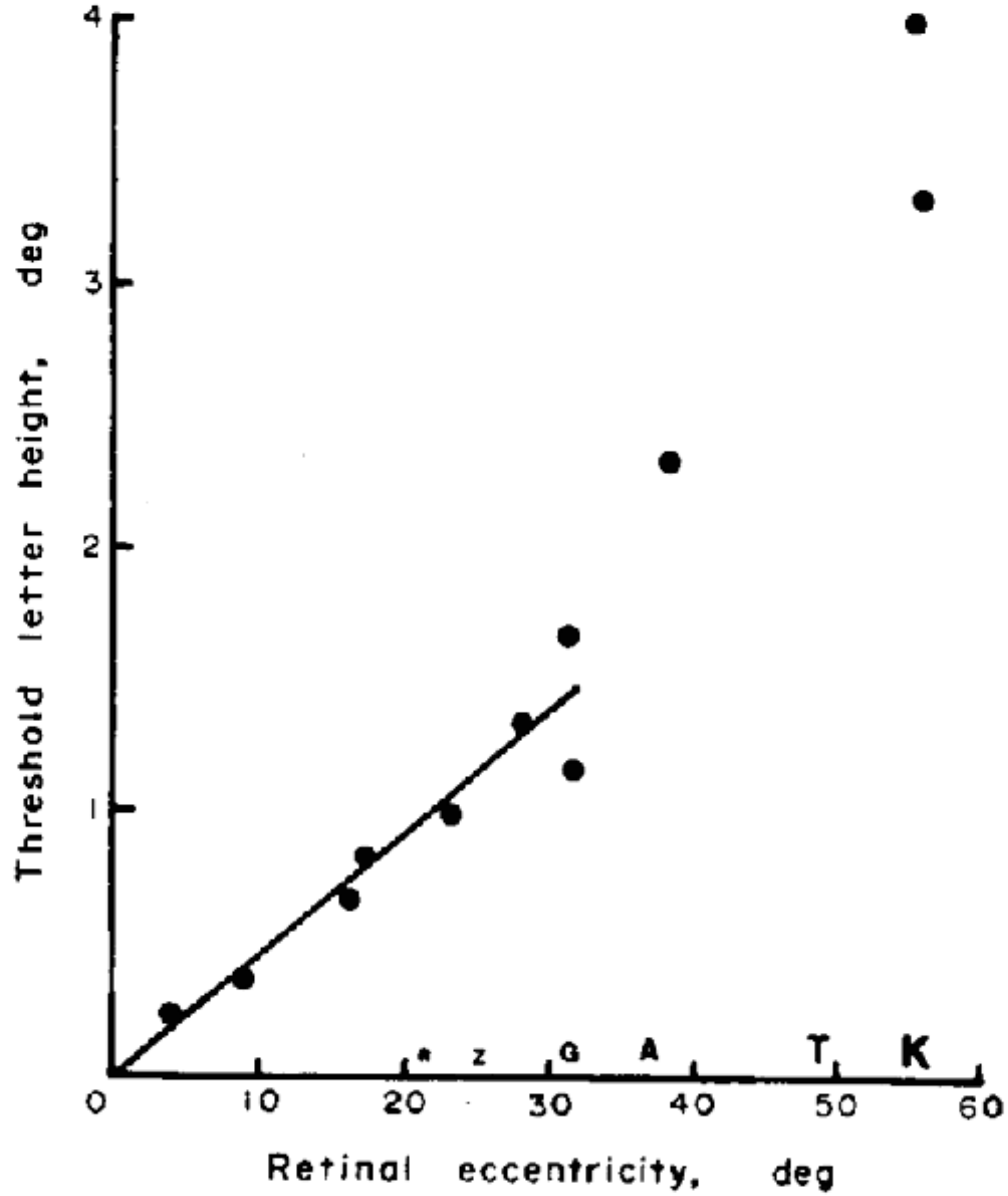
(shown at one dot for every 20 ganglion cells)




$$\Delta \approx .01(|E|+1)$$

(from Anderson & Van Essen, 1995)

# Letter size vs. eccentricity
(Anstis, 1974)



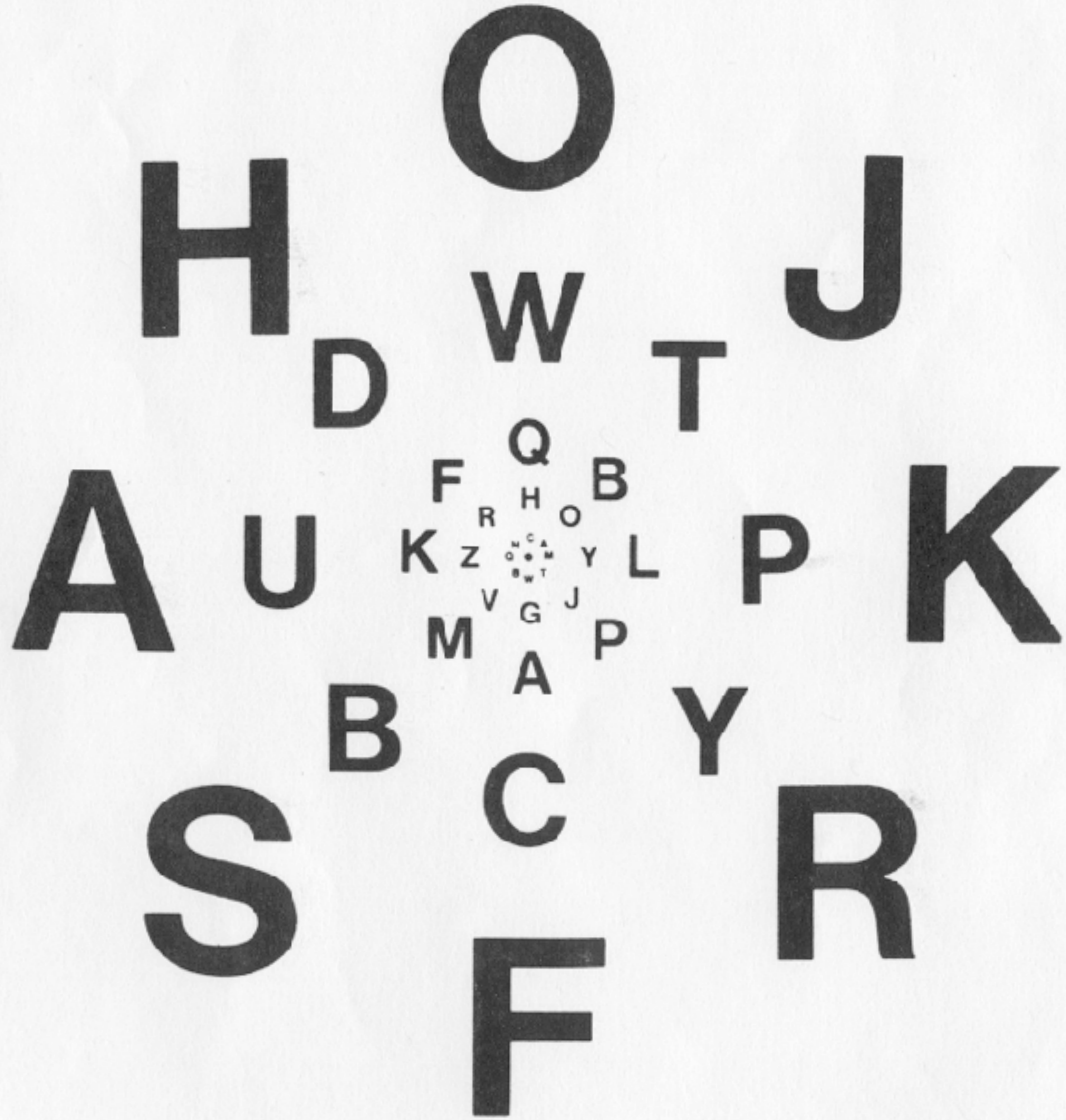



Fig. 3. All letters should be equally readable when centre of this chart is fixated, since each letter is ten times its threshold height.

+ N

+ ENE

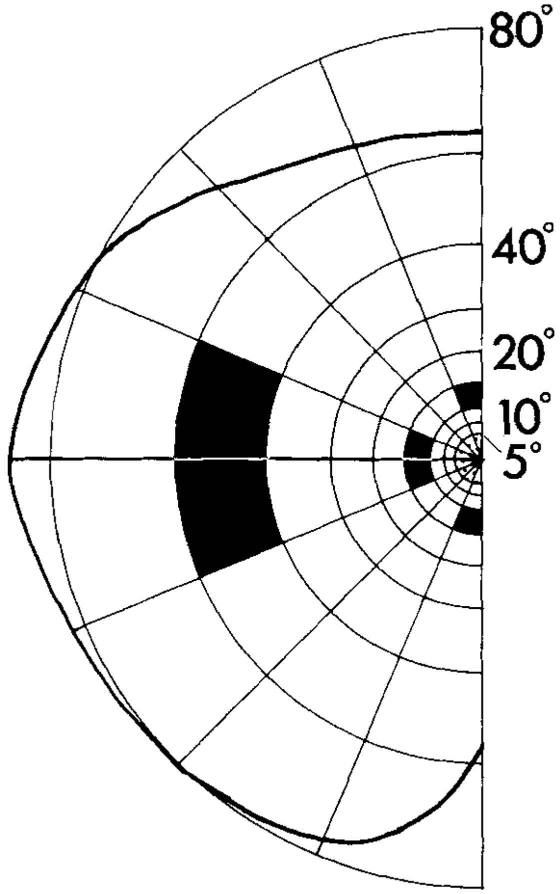
ENE

# ‘Crowding’

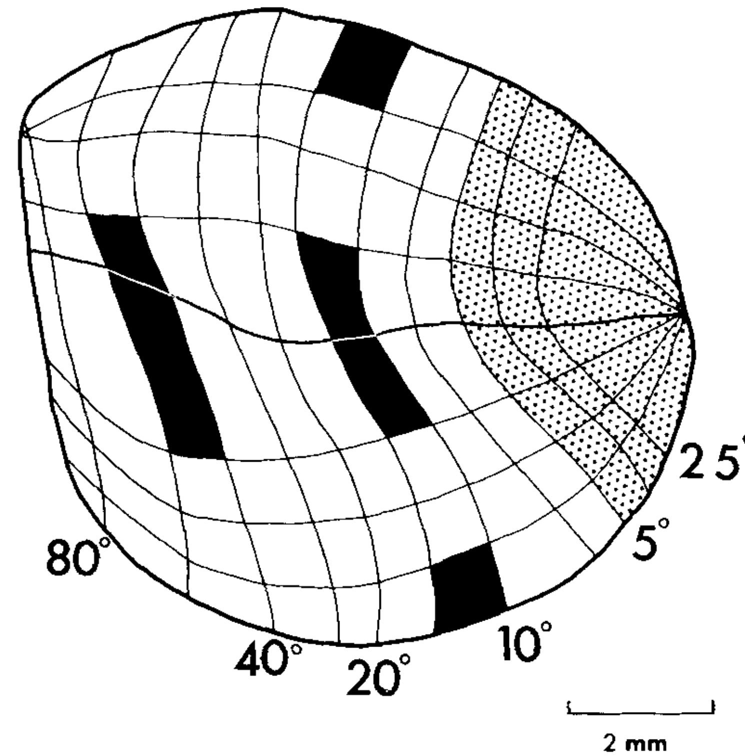
From: Whitney & Levi (2011)


0:00 / 0:54
HD
YouTube

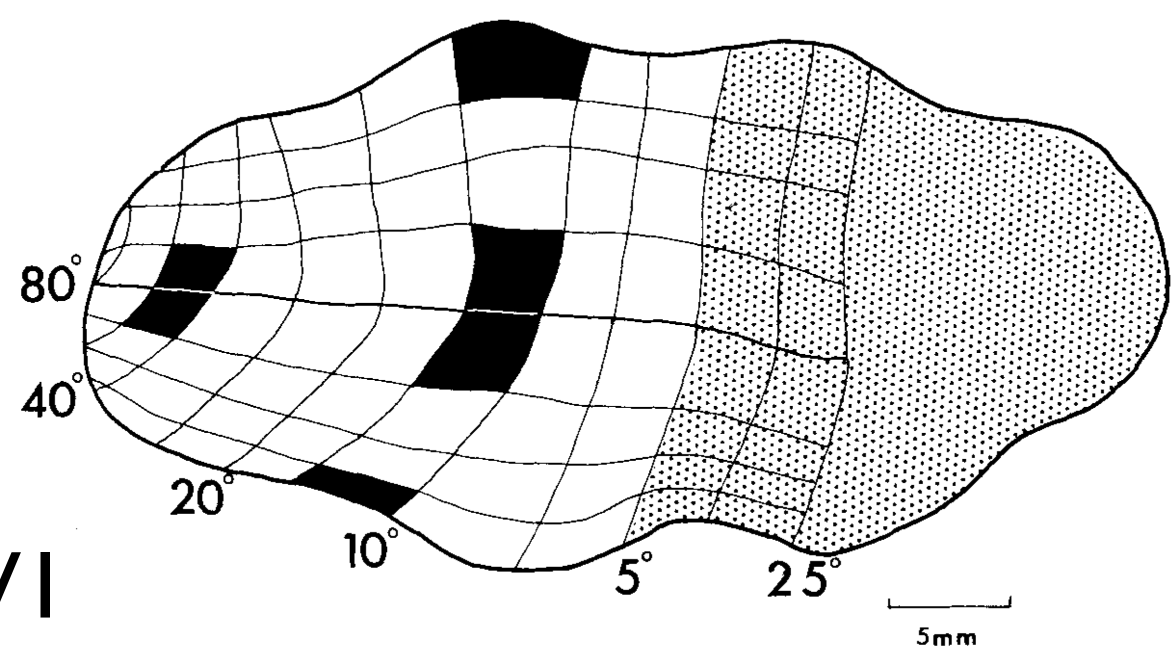
# Foveal oversampling in LGN and Cortex
## (Connolly & Van Essen, 1984)




LGN




"…despite the fact that the estimated total number of LGN cells is similar to the total number of retinal ganglion cells, their ratio must vary from many LGN cells per retinal ganglion cell for the fovea to fewer than one LGN cell per retinal ganglion cell in the periphery."

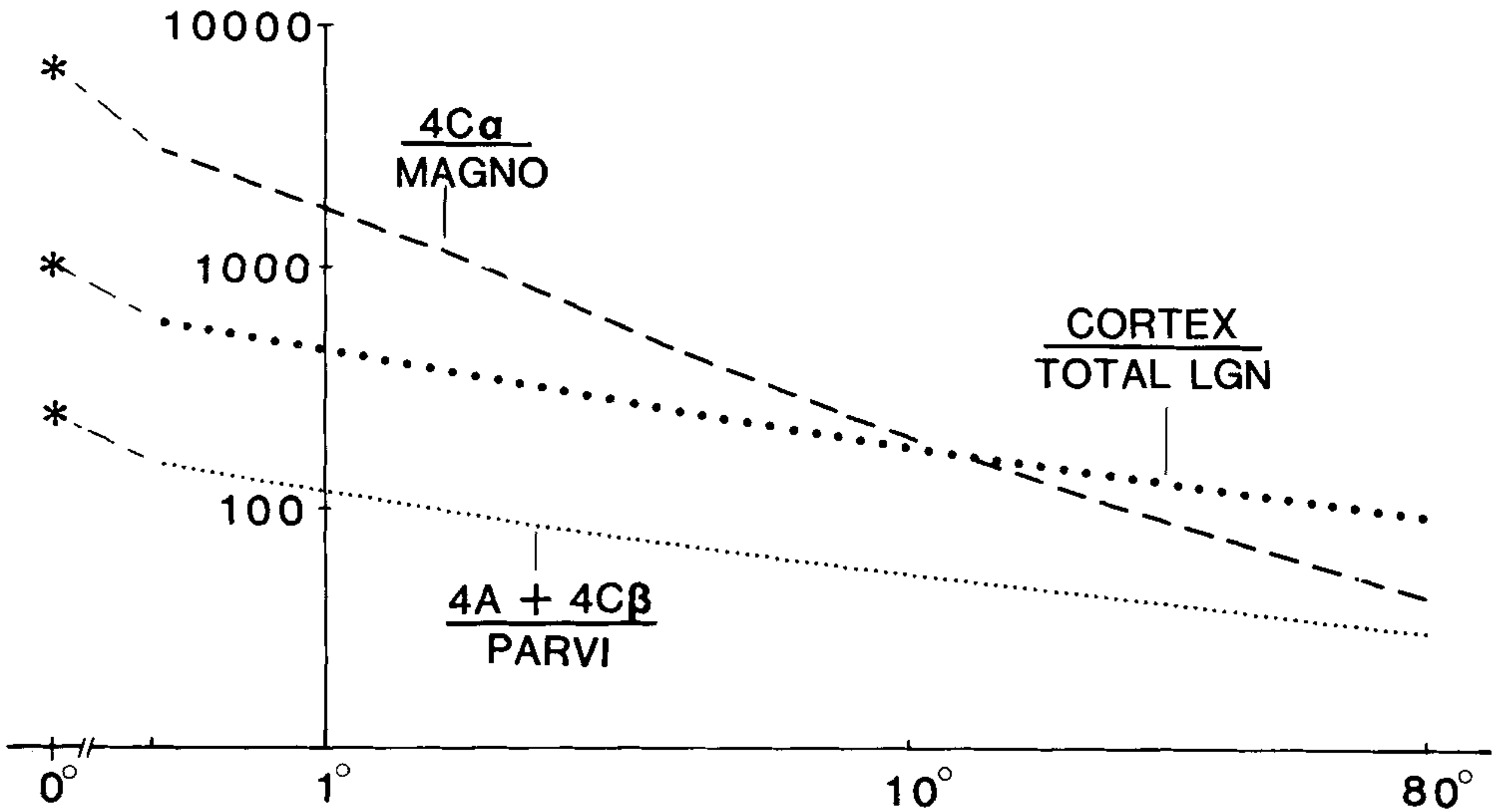



V1

# Cortex:LGN cell ratio ranges from 1000:1 in fovea to 100:1 in periphery

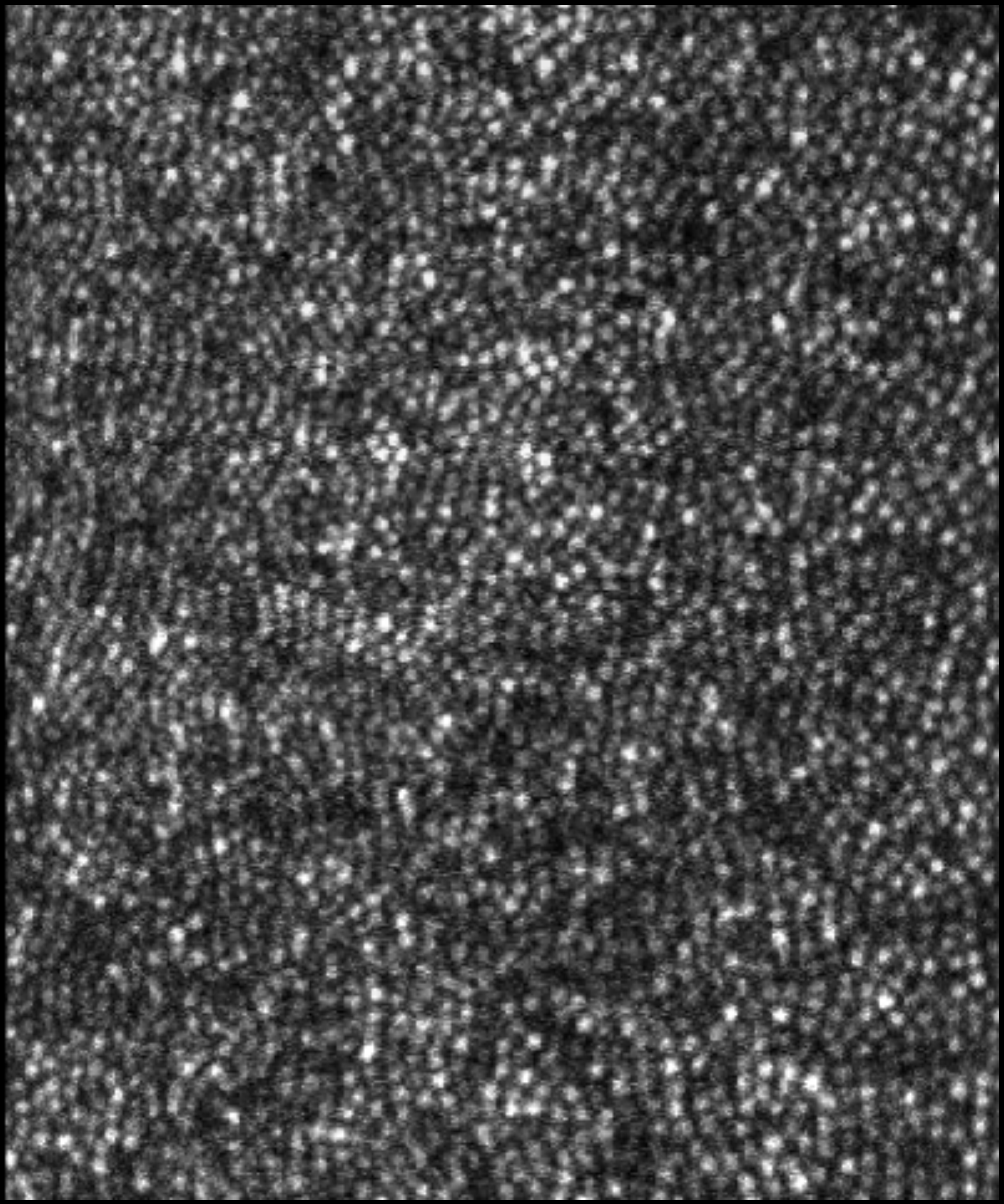
(Connolly & Van Essen, 1984)

Cortex:LGN cell ratio




Eccentricity

# Fixational eye movements (drift)

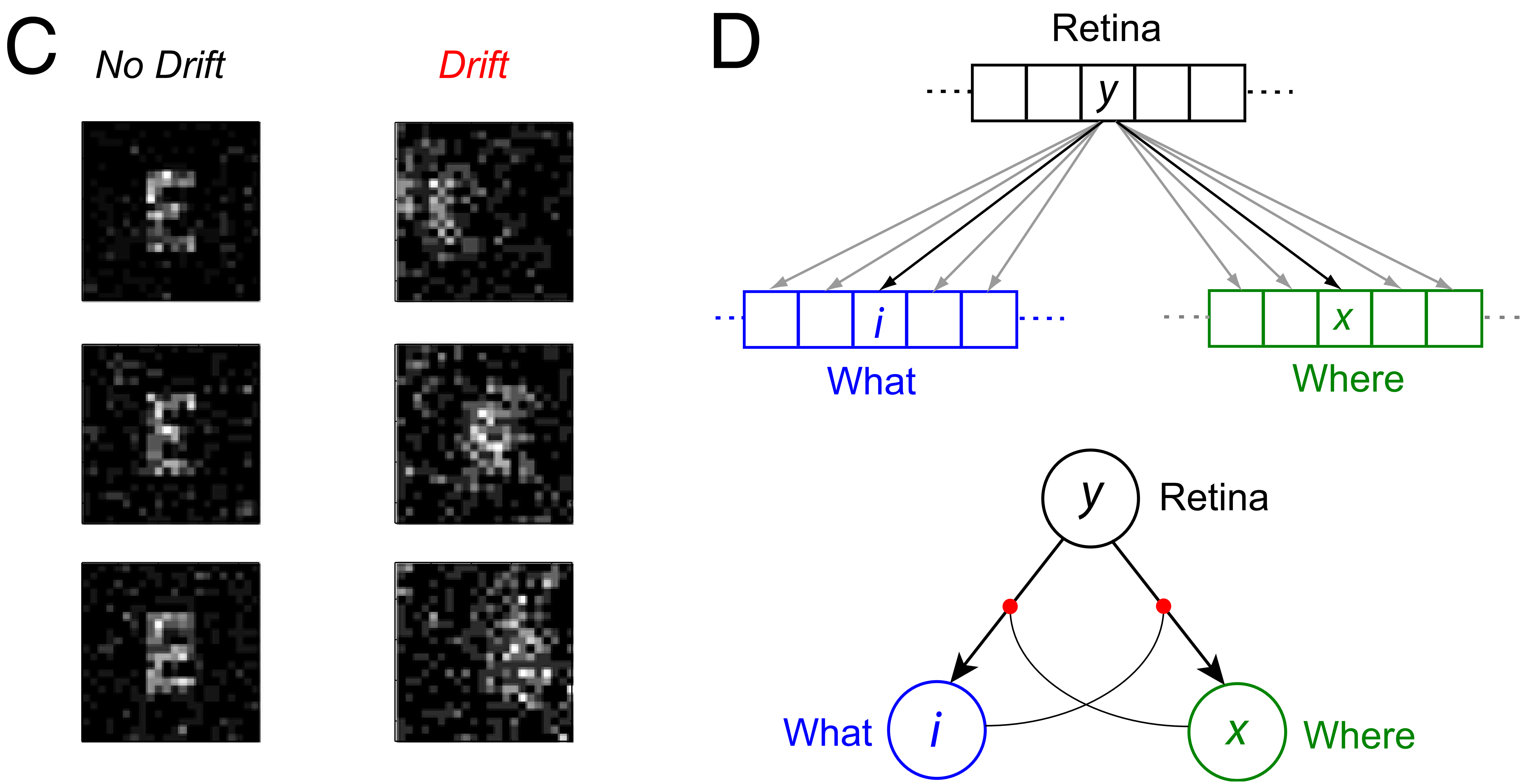


(from Austin Roorda, UC Berkeley)

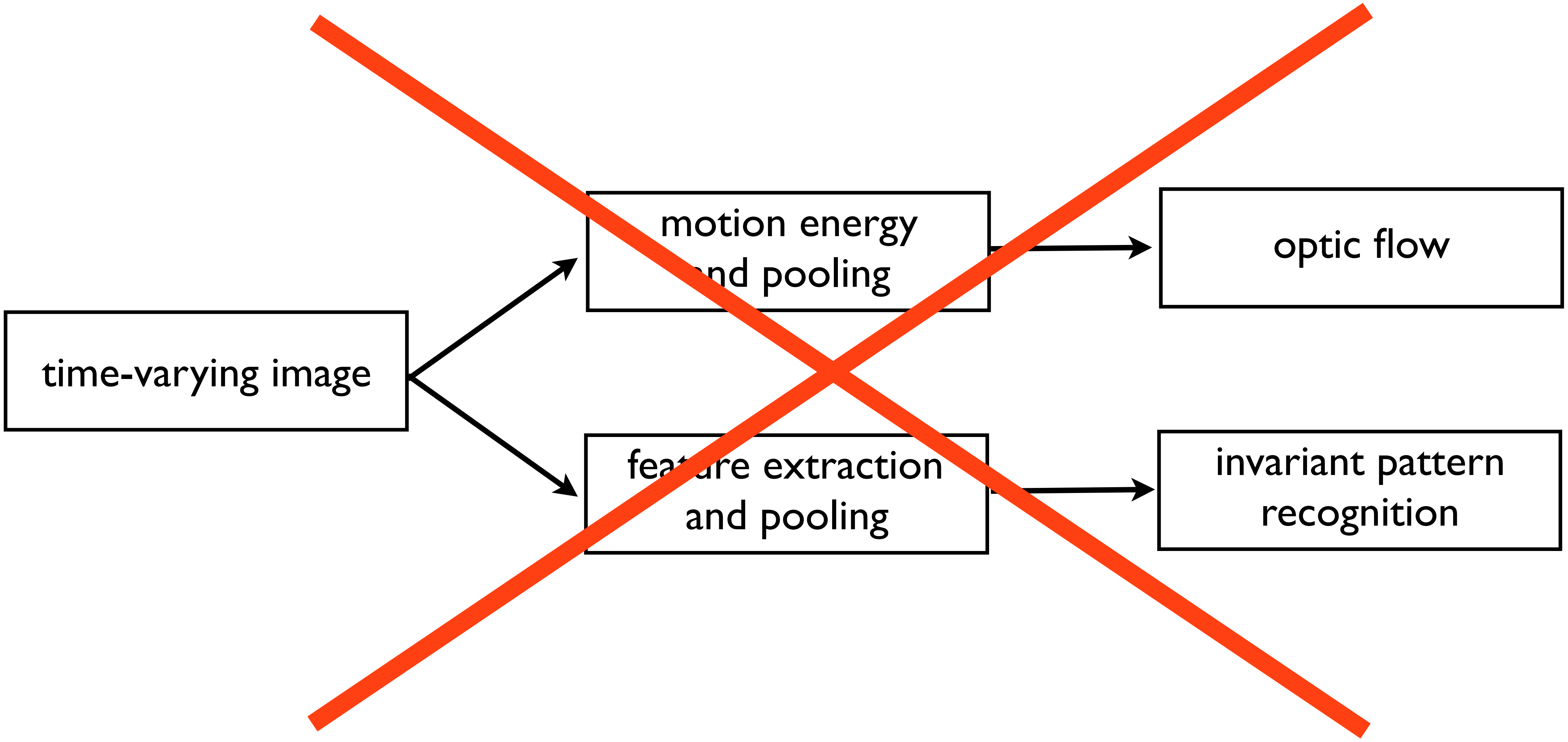
PNAS | November 9, 2010 | vol. 107 | no. 45 | 19525–19530

# Bayesian model of dynamic image stabilization in the visual system

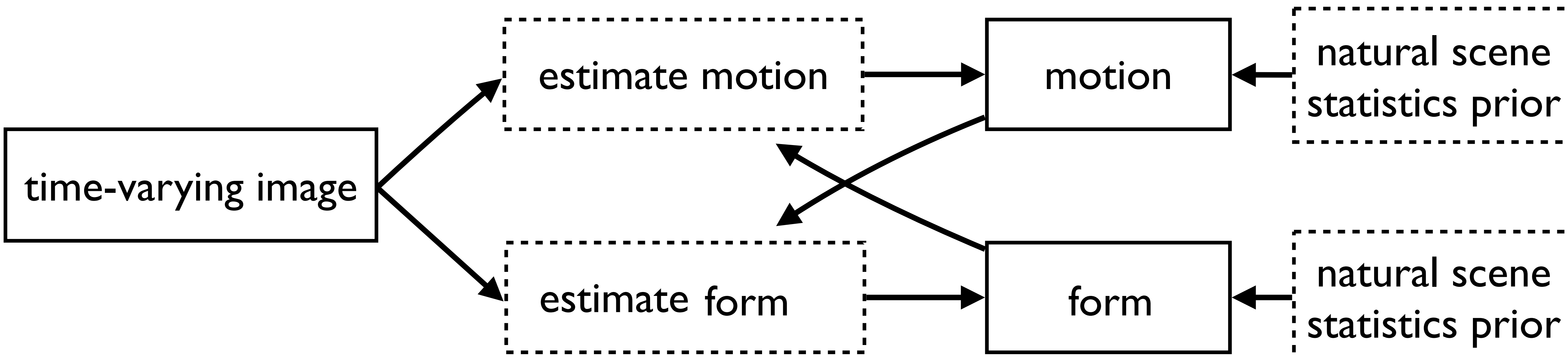
Yoram Burak[a], Uri Rokni[a], Markus Meister[a,b], and Haim Sompolinsky[a,c,1]



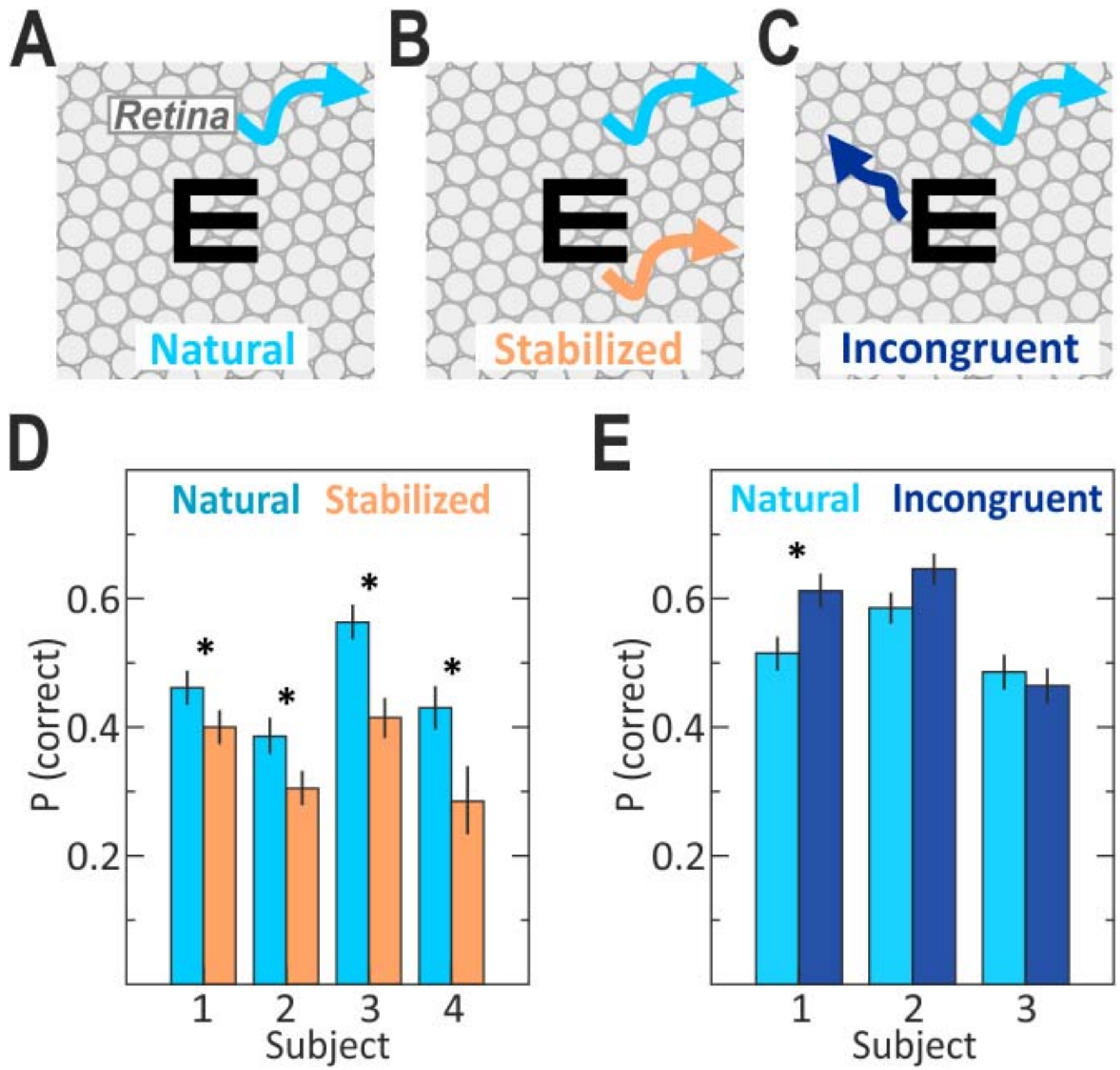
# Traditional models compute motion and form independently



# Motion *and* form must be estimated simultaneously



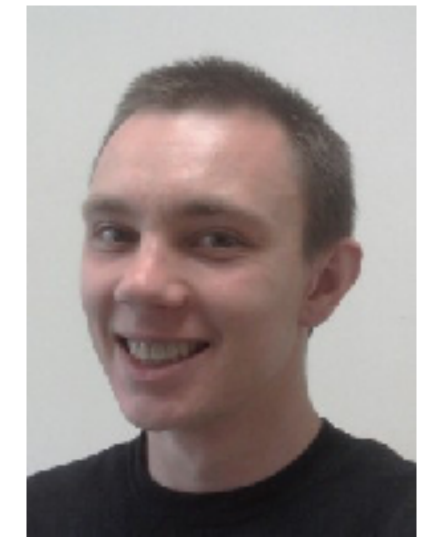
# Retinal image motion <u>helps</u> pattern discrimination

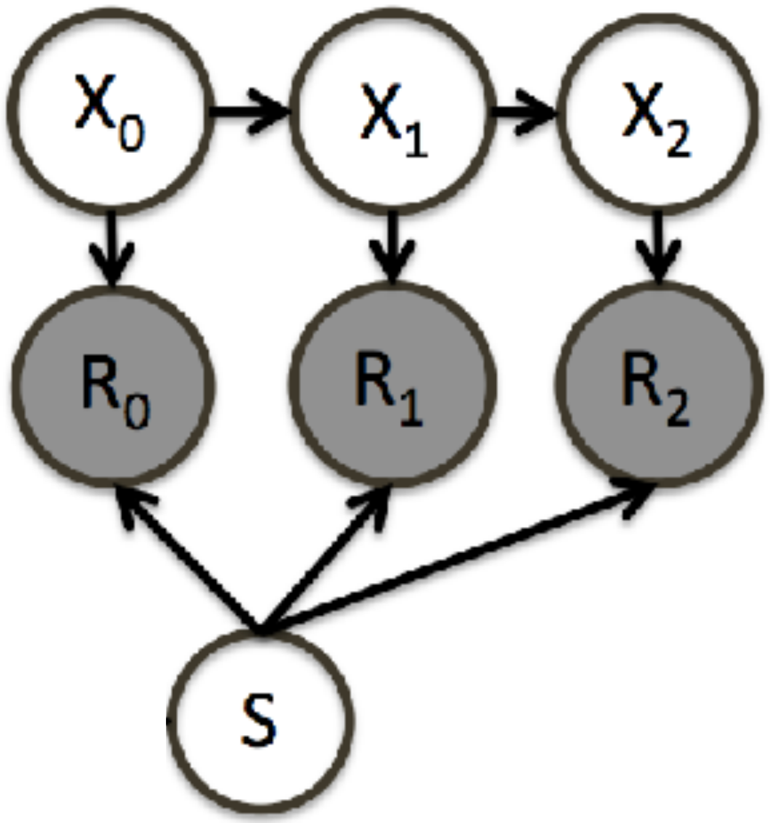



Ratnam, K., Domdei, N., Harmening, W. M., & Roorda, A. (2017). Benefits of retinal image motion at the limits of spatial vision. *Journal of Vision, 17*, 1–11.

# Graphical model for separating form and motion

(Alex Anderson, Ph.D. thesis)






**Eye position**

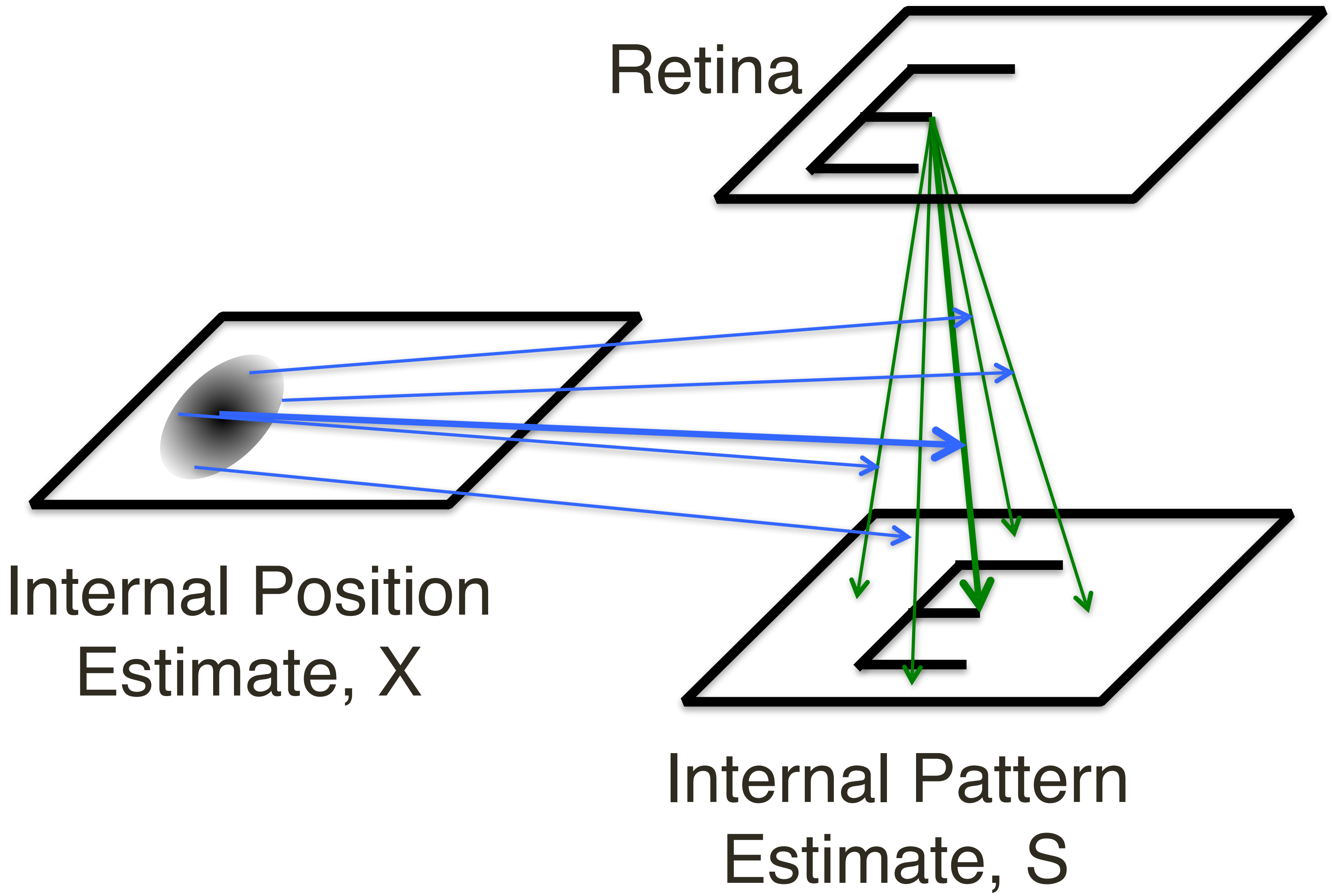
**Spikes**

(from LGN afferents)

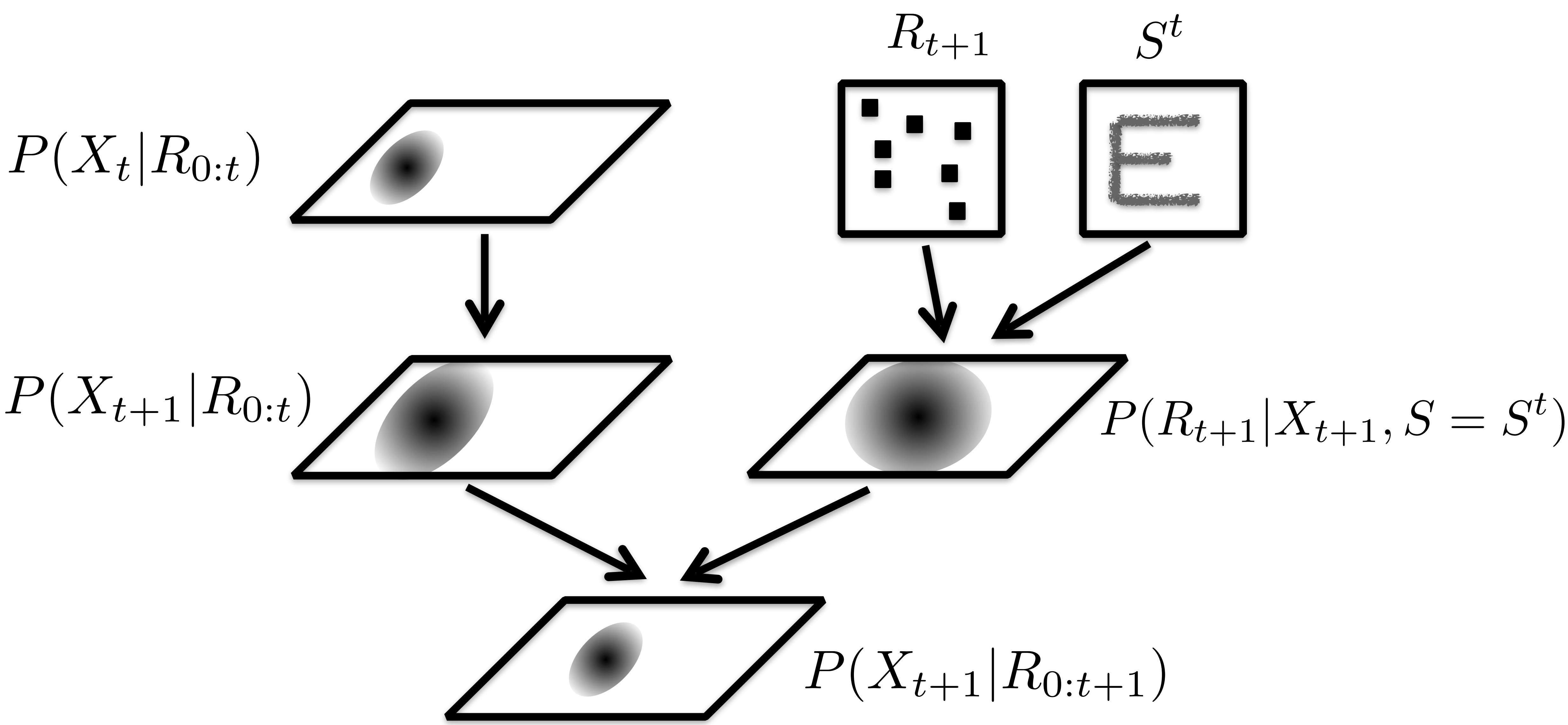
**Pattern**

$$\hat{S} \quad = \quad \arg\max_{S} \log P(R|S)$$

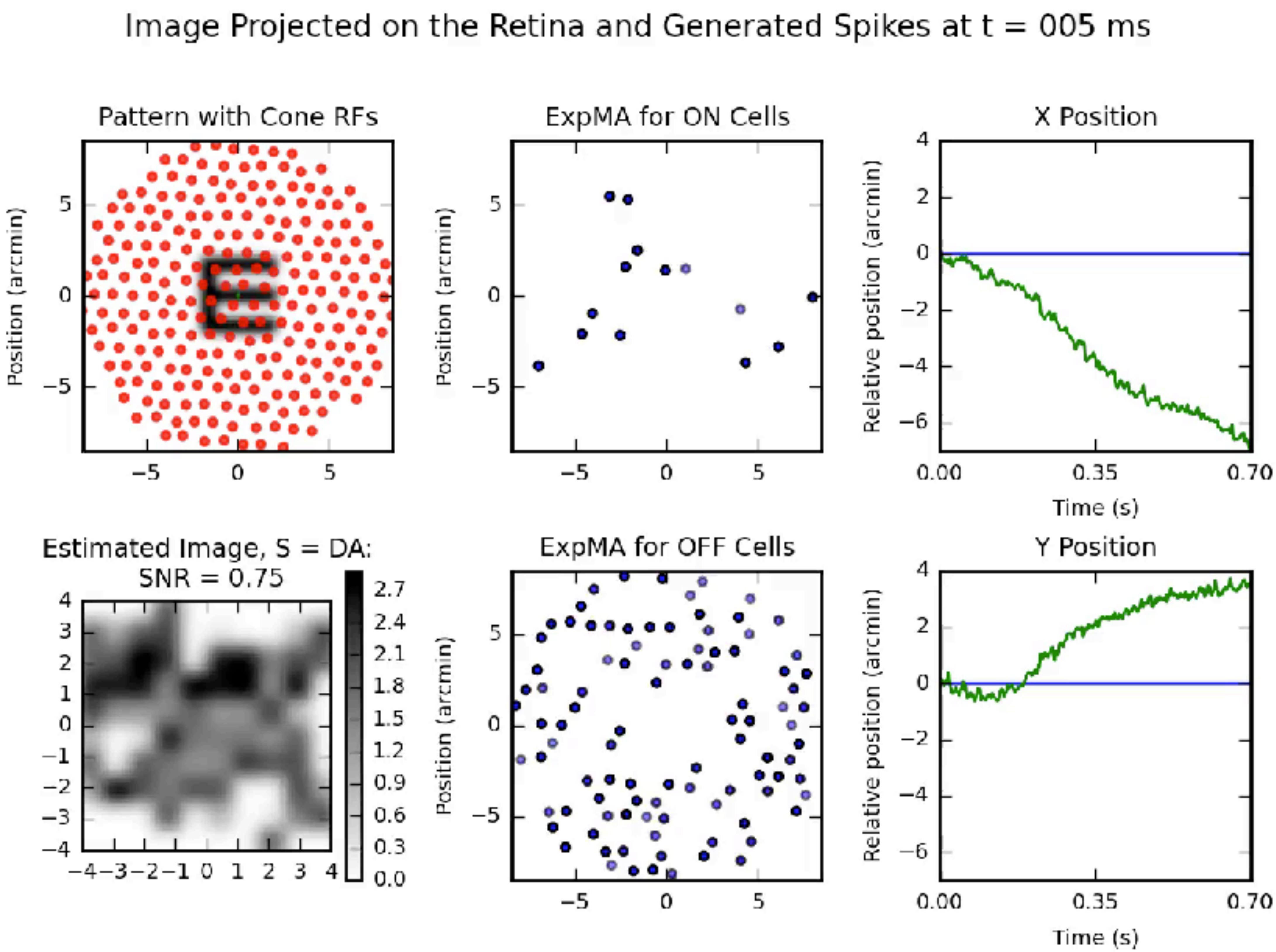
# Given current estimate of position (X), update S



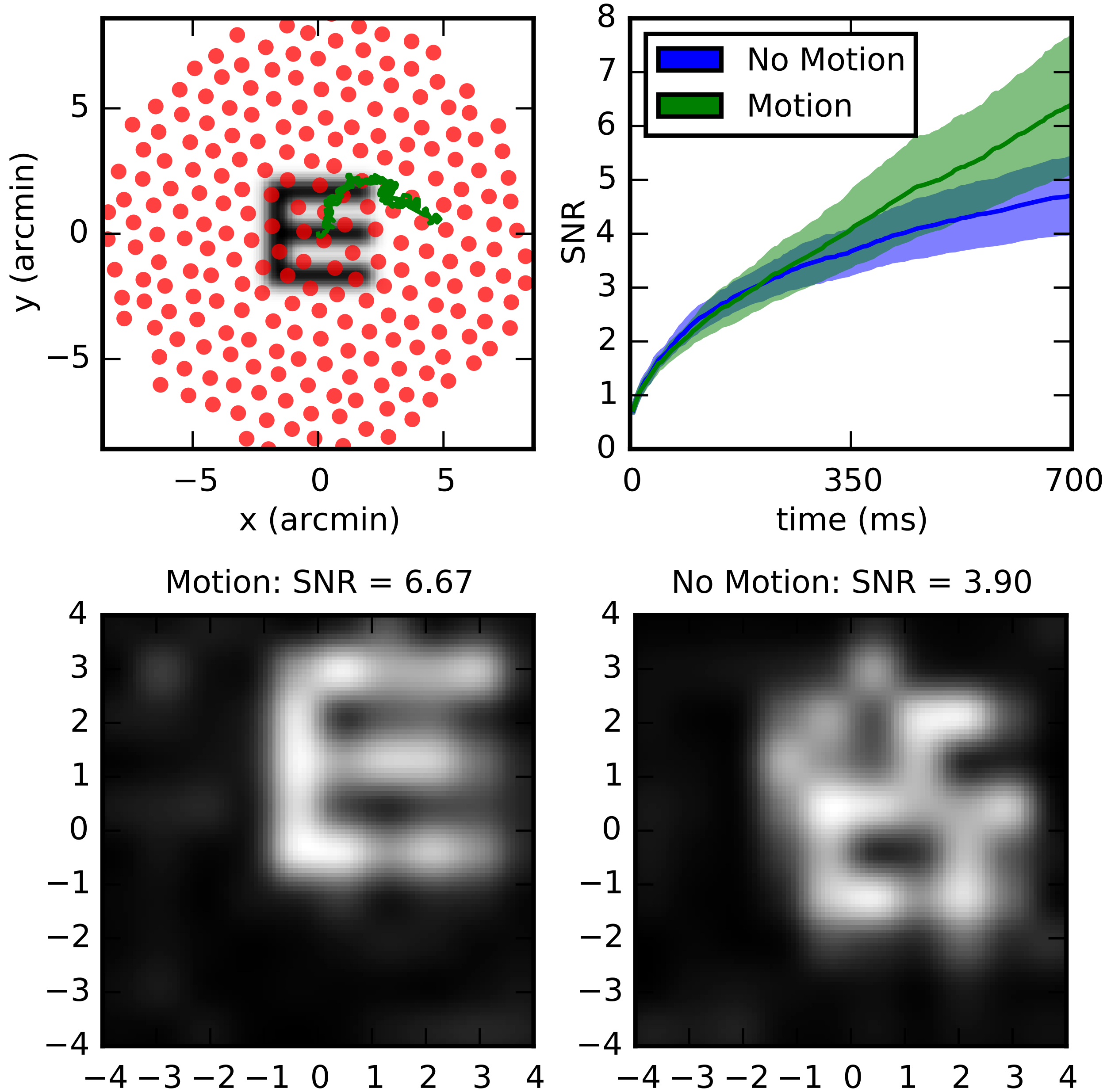
# Given current estimate of pattern (S), update X



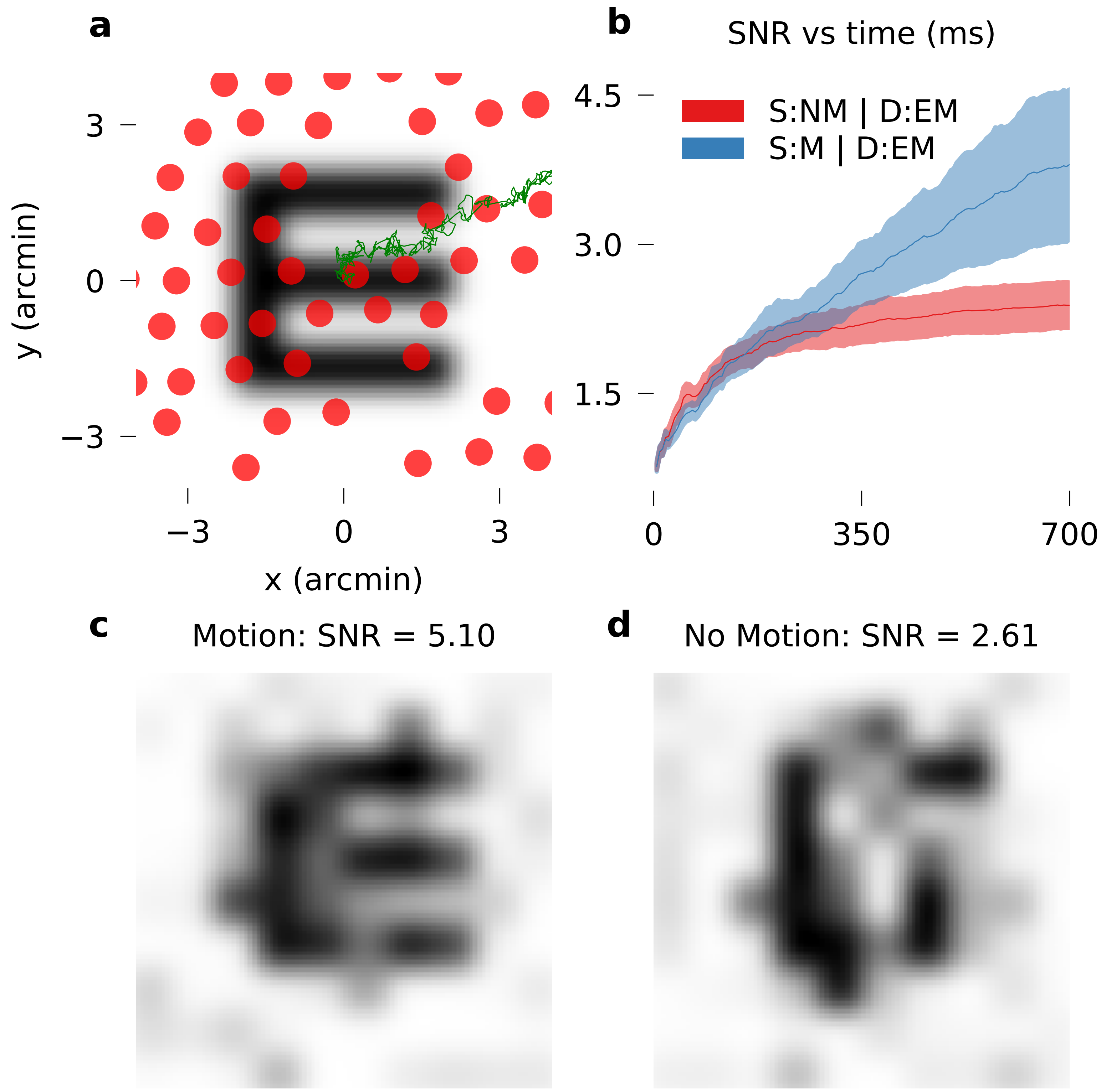
# Joint estimation of form and motion
(Alex Anderson, Ph.D. thesis)



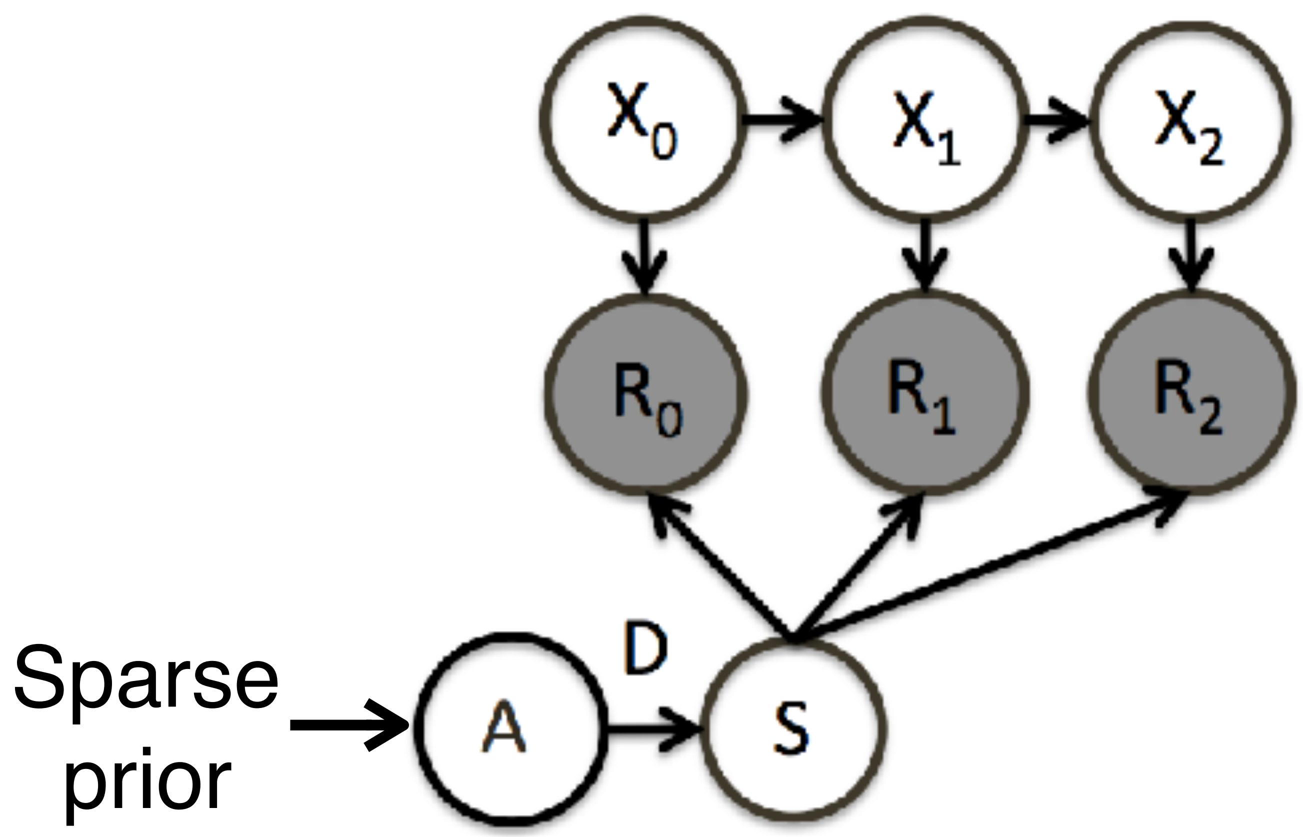
# Motion <u>helps</u> estimation of pattern *S*



# Motion restores acuity in the case of cone loss



# Including a prior over *S*




**Eye position**

**Spikes**
(from LGN afferents)

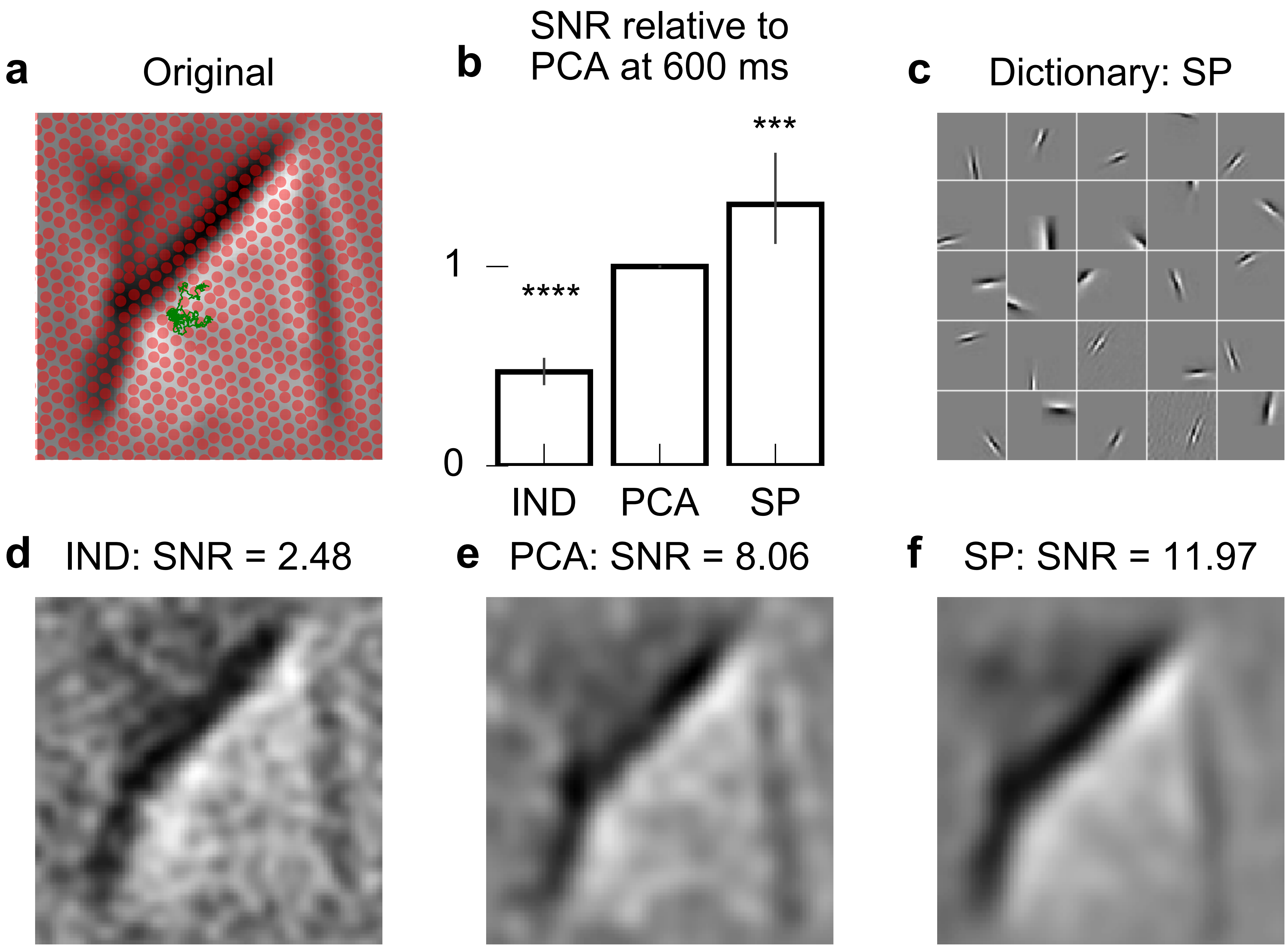
**Pattern**

$$S = D\,A$$

$$\hat{A} = \arg\max_{A}\ \log P(R|A) + \log P(A)$$

sparse

# Natural image pattern may be inferred with a sparse prior using a Gabor-like basis similar to V1 receptive fields



# Main points

- The foveal representation in LGN, and again in cortex, is highly oversampled, *in terms of number of neurons per ganglion cell*, with respect to the periphery.

- Phenomena such as crowding and shape adaptation suggest a looser representation of shape in the periphery that is more subject to grouping or contextual influences than in the fovea.

- Neural circuits in the foveal portion of V1 *must* take into account estimates of eye position or motion in order to properly integrate spatial information.

- One possibility is separate populations of neurons that interact multiplicatively in order to explicitly disentangle form and motion.