Understanding vision through the lens of prediction

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Prediction in the retina

- the retina does computation
- the retina does prediction
- the retina does prediction *optimally*

Towards more natural stimuli

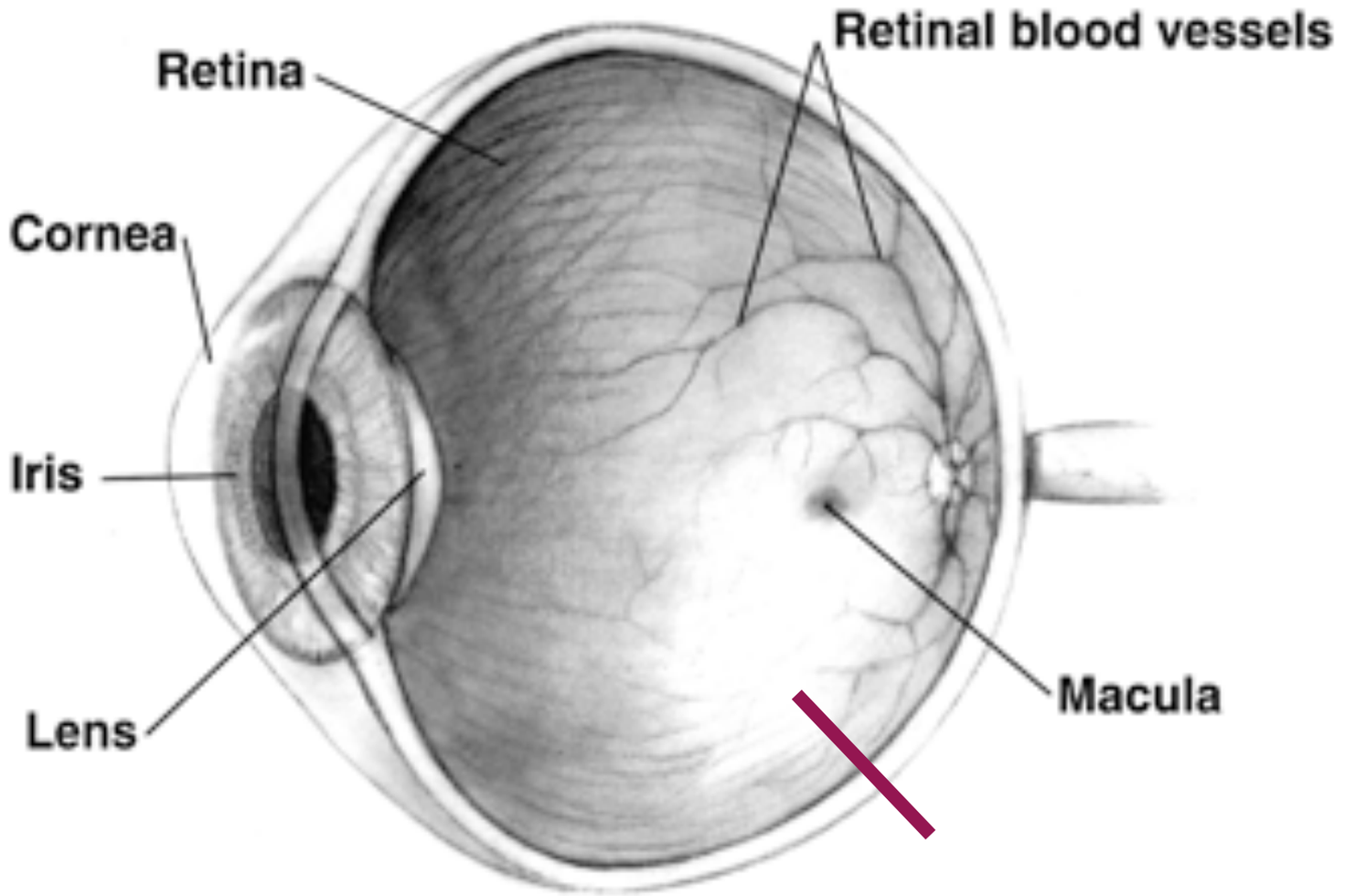
- the *Chicago Motion Database*
- natural motion statistics

Evolution of neural computation

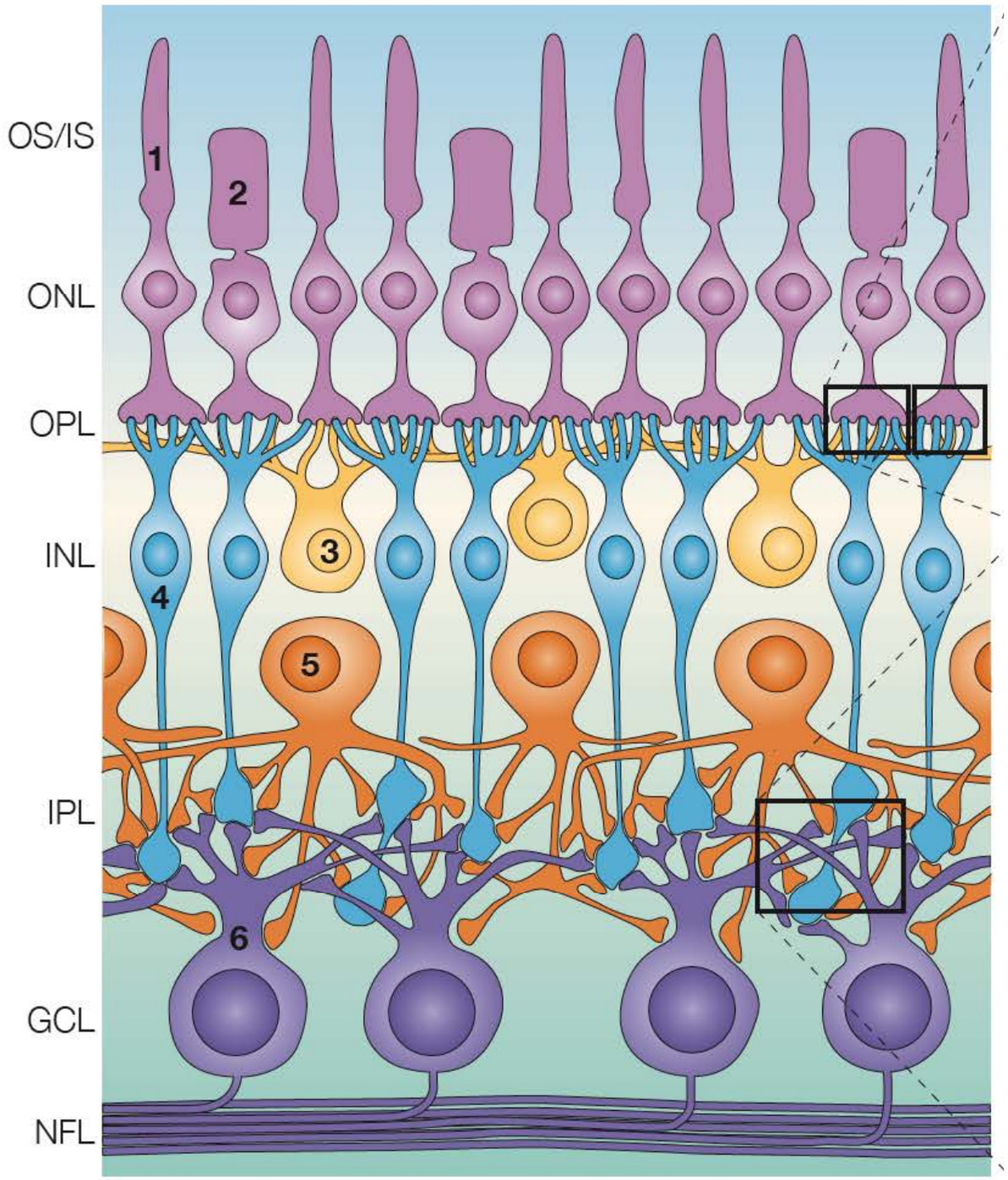
- color vision in butterflies

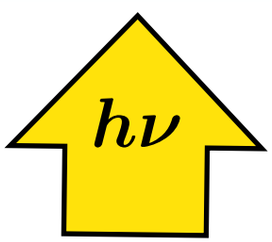
Why does the brain need to make predictions?

Basic eye anatomy:



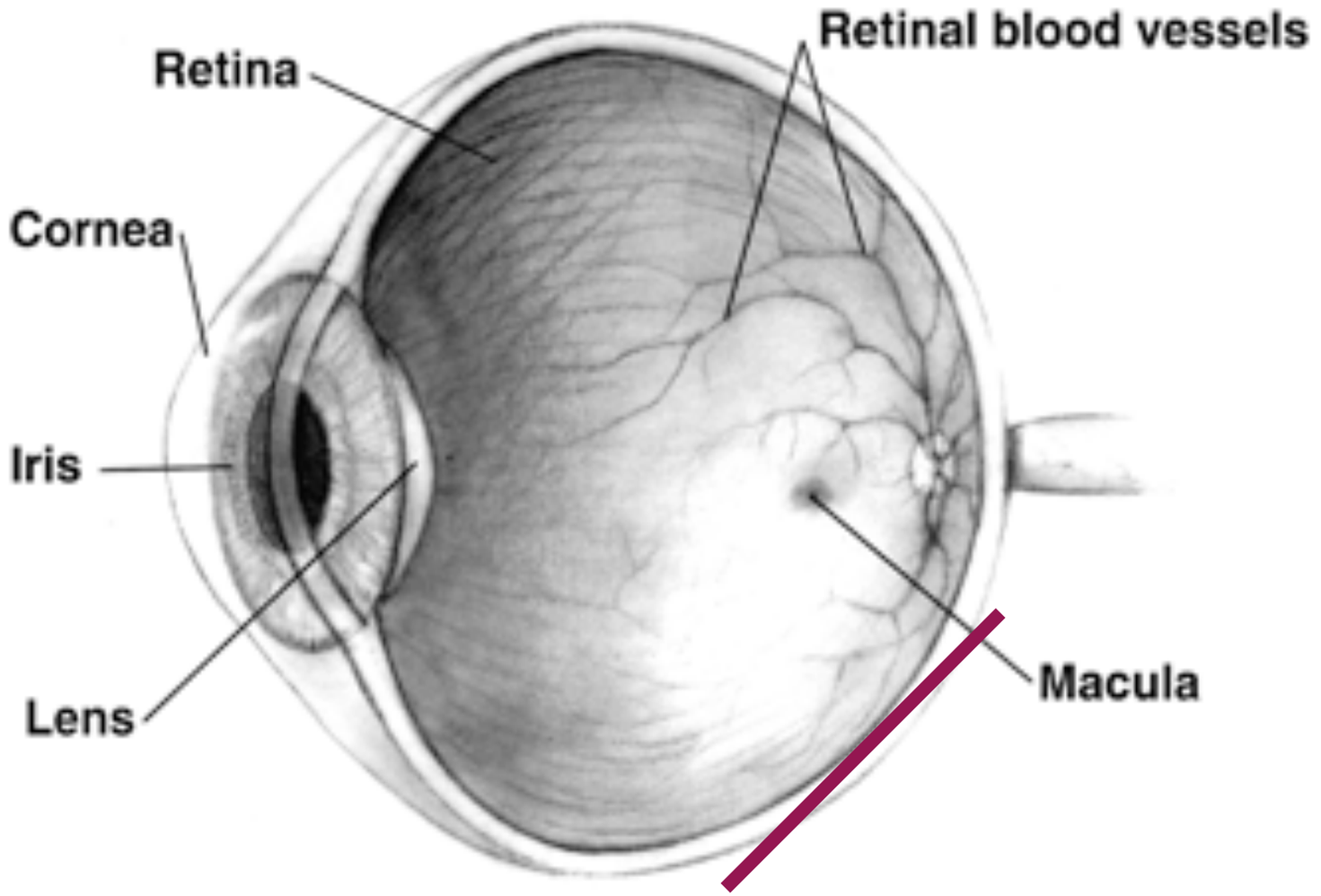
The cellular organization of the retina:

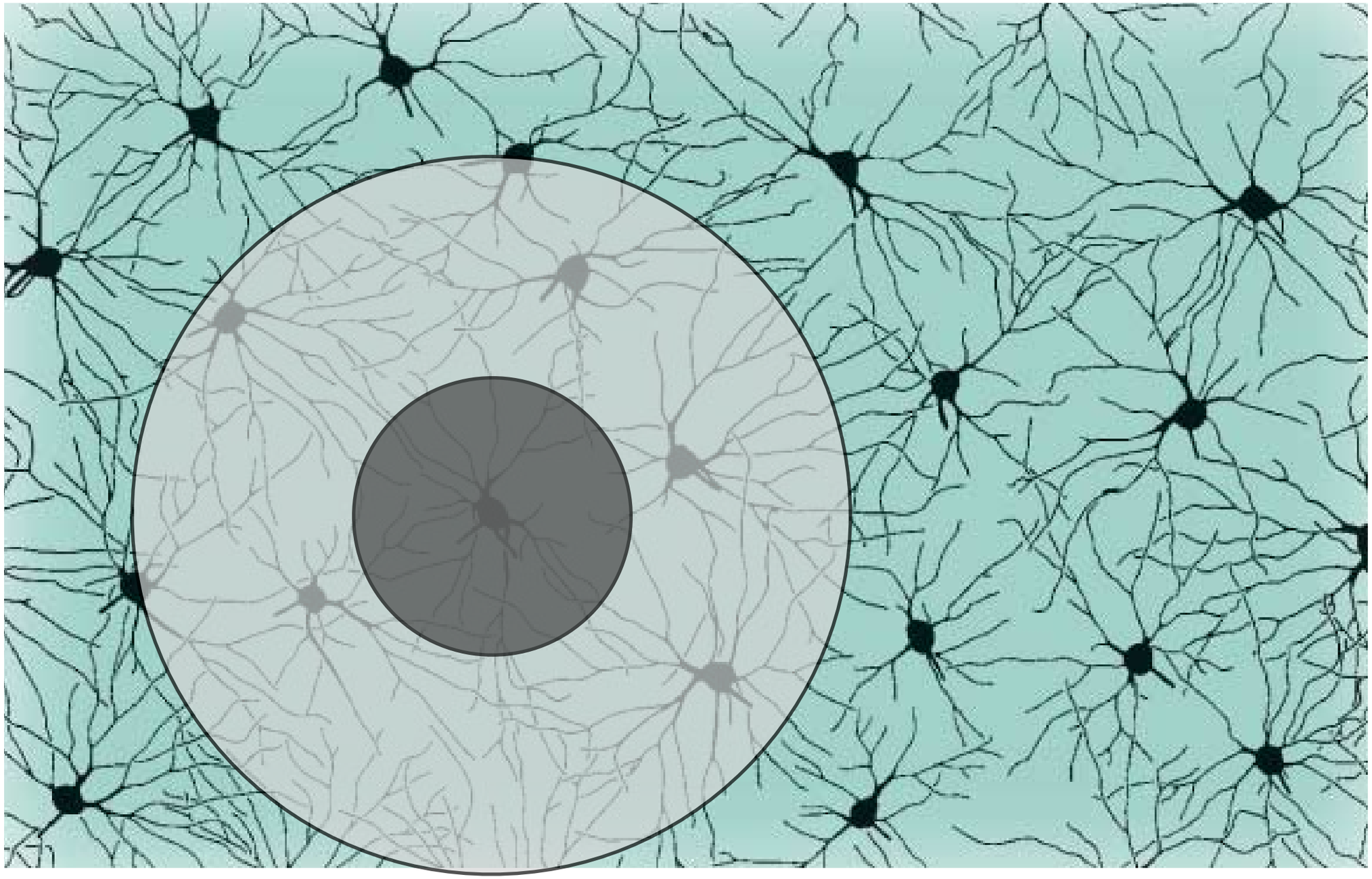




H Wassle, *Nature Reviews Neurosci* (2004)

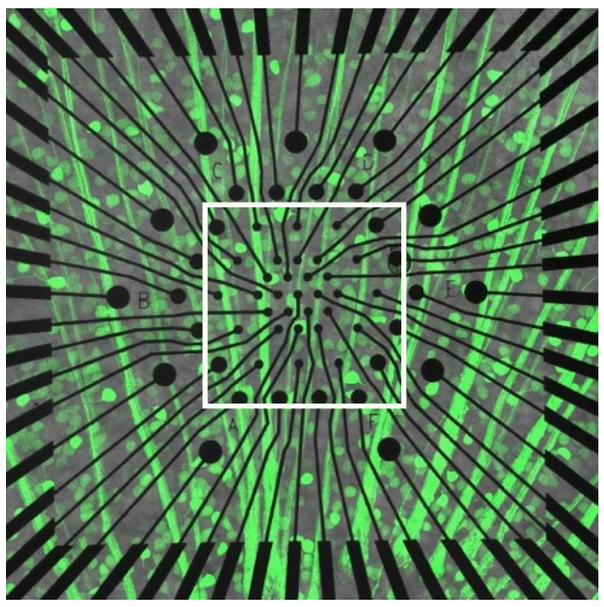
Basic eye anatomy:

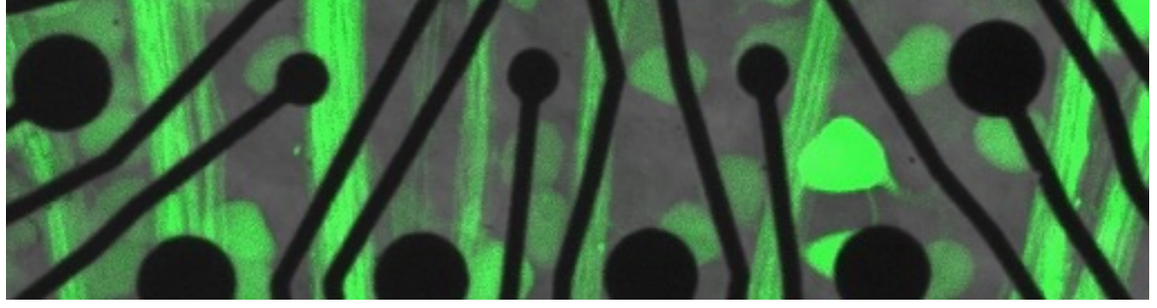




H Wassle, *Nature Reviews Neurosci* (2004)

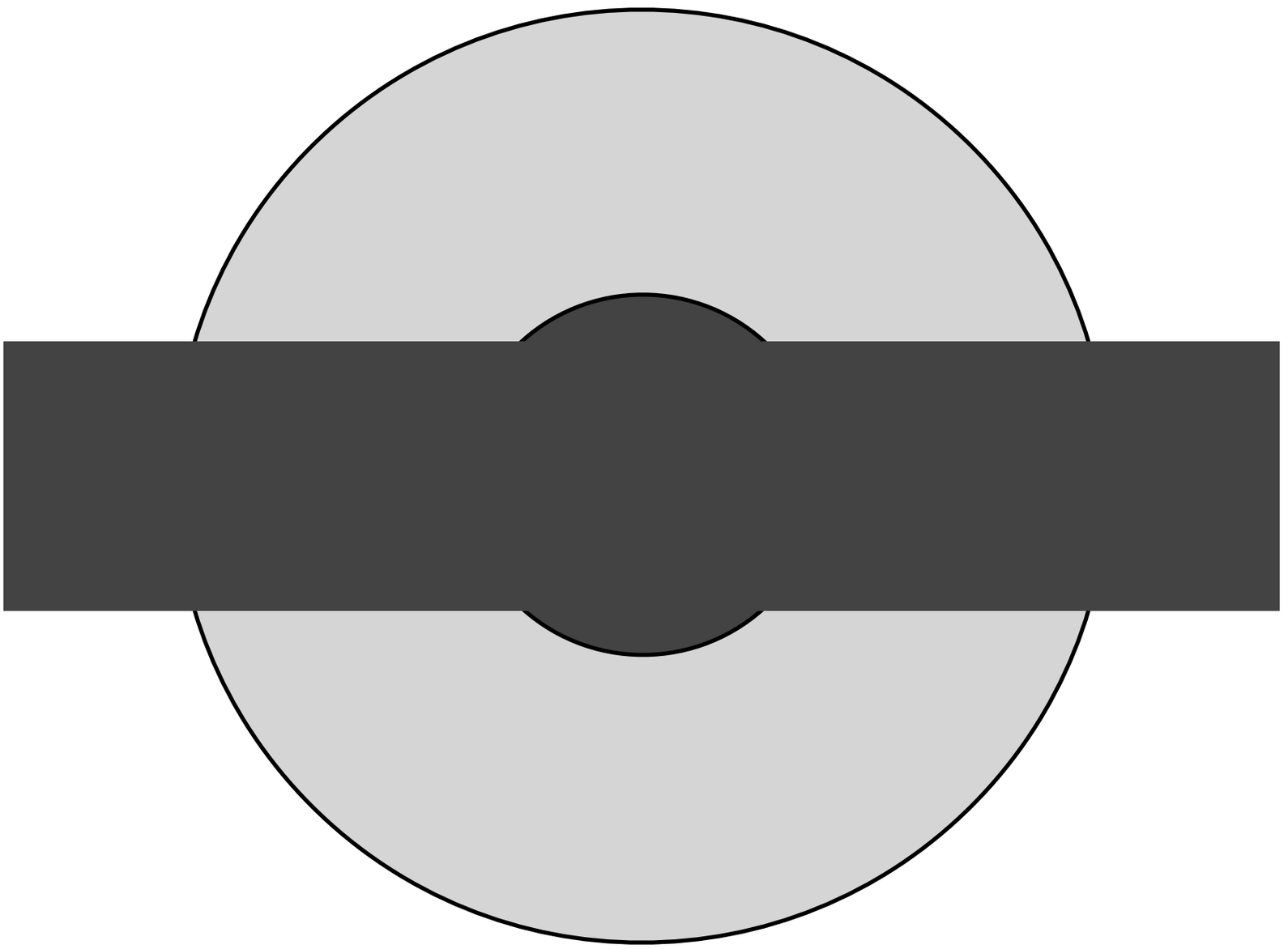
Recording from the retina:



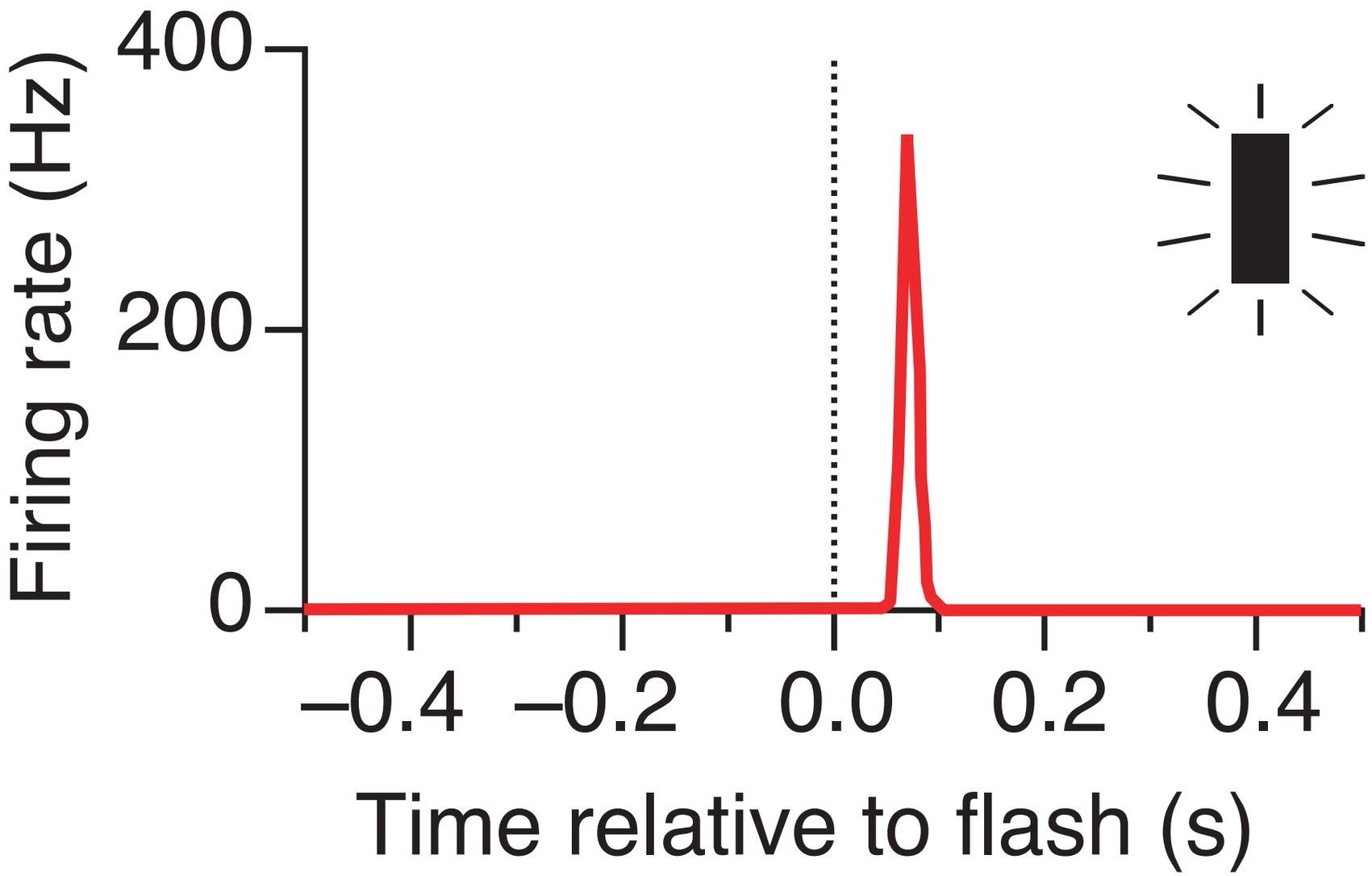


$30\mu\mathrm{m}$

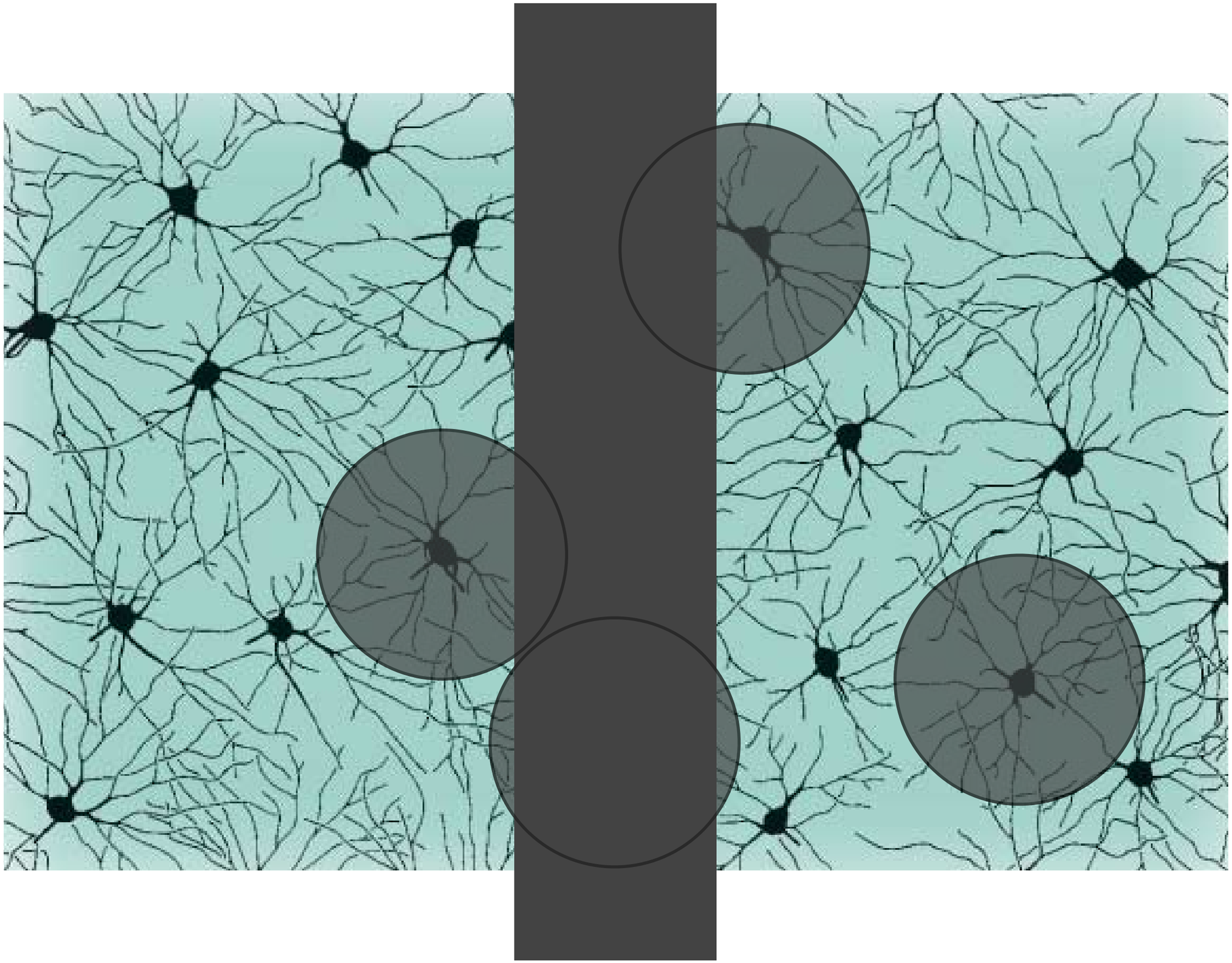
images from the Berry lab



Retinal ganglion cell response to a flashed bar:

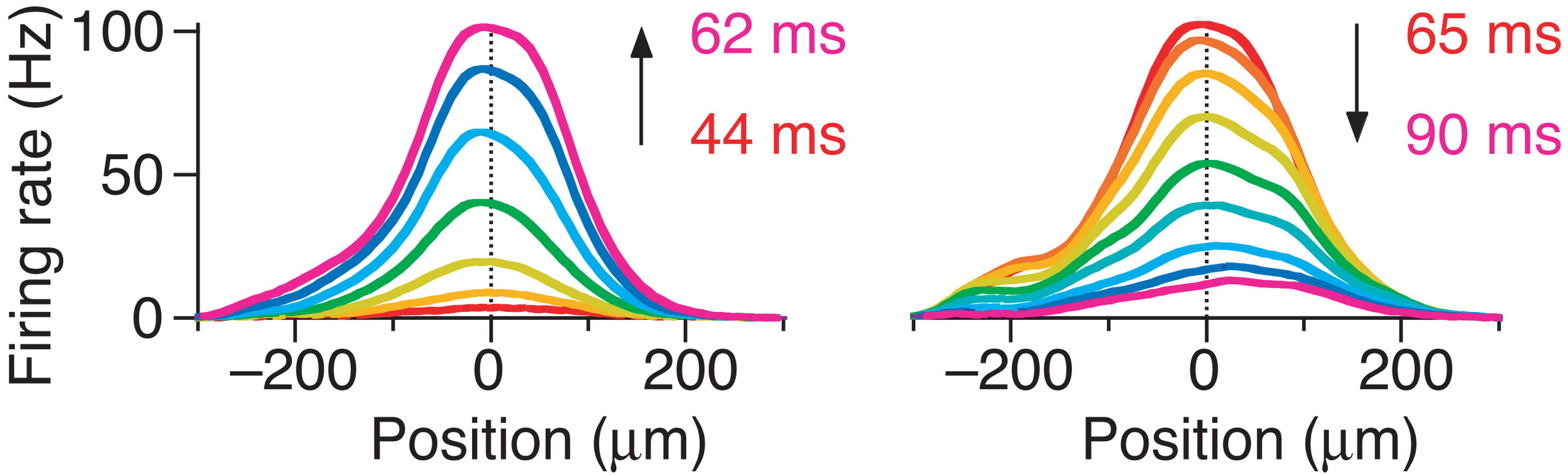


Berry and Meister 1999

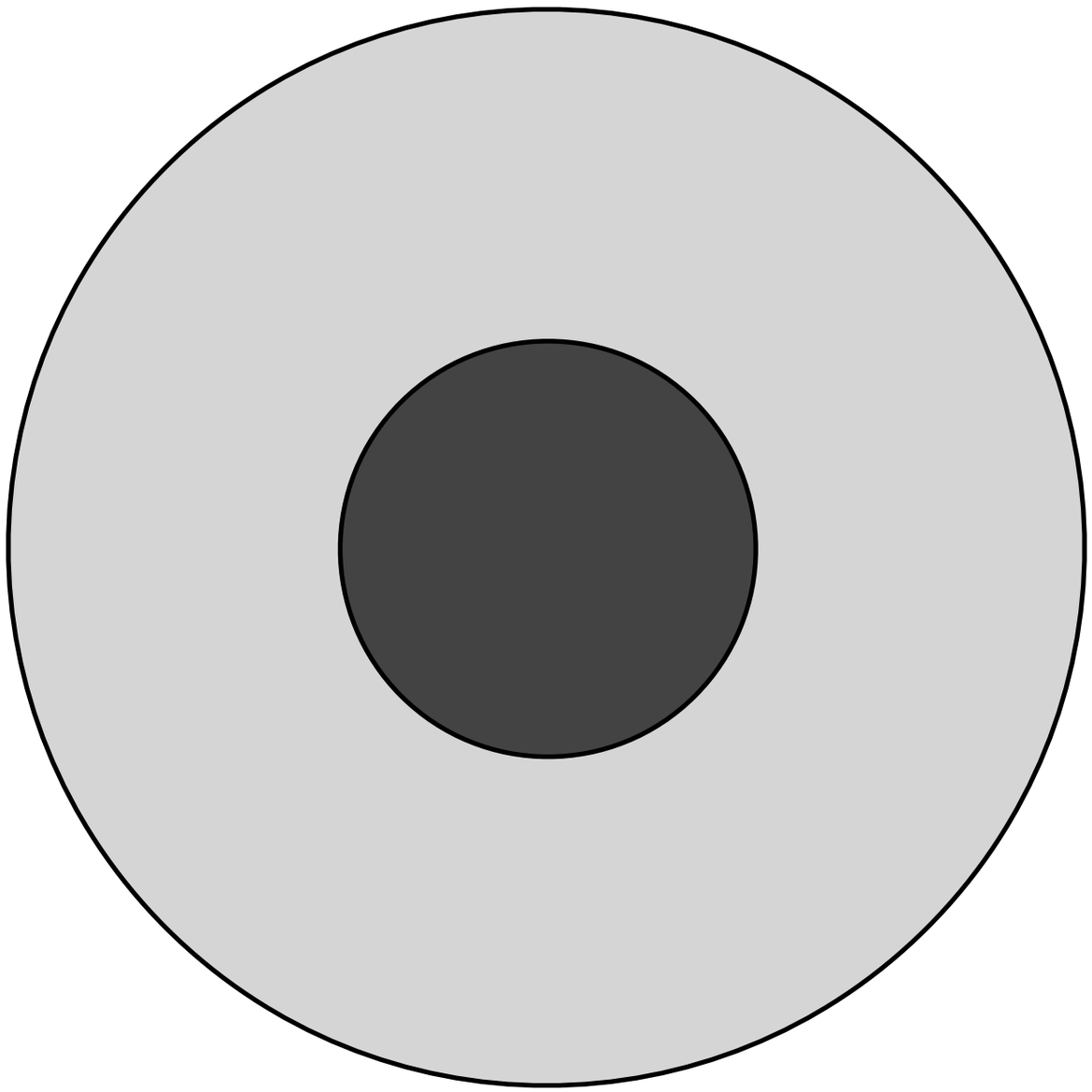


H Wassle, *Nature Reviews Neurosci* (2004)

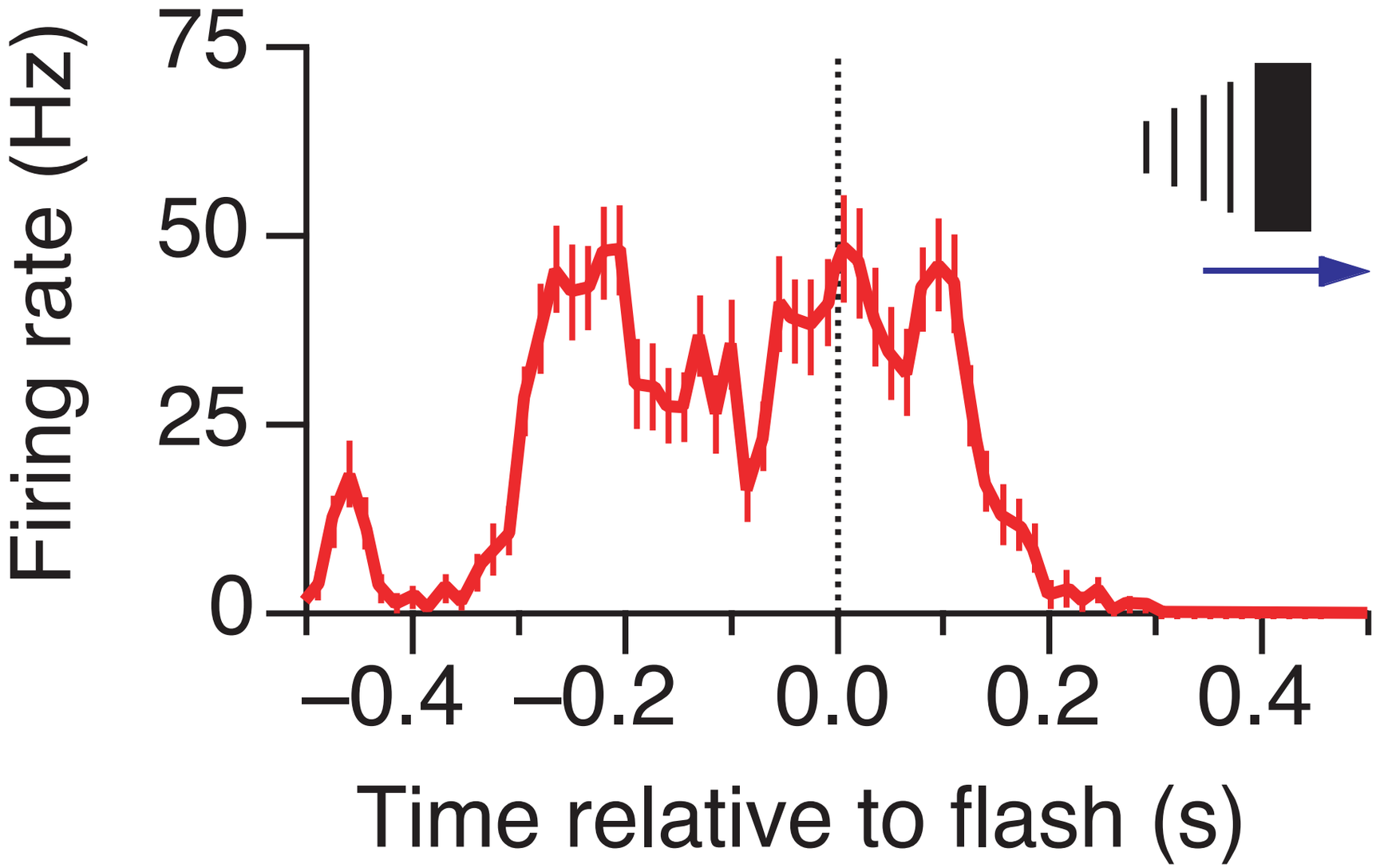
Response across the retina to a flashed bar:



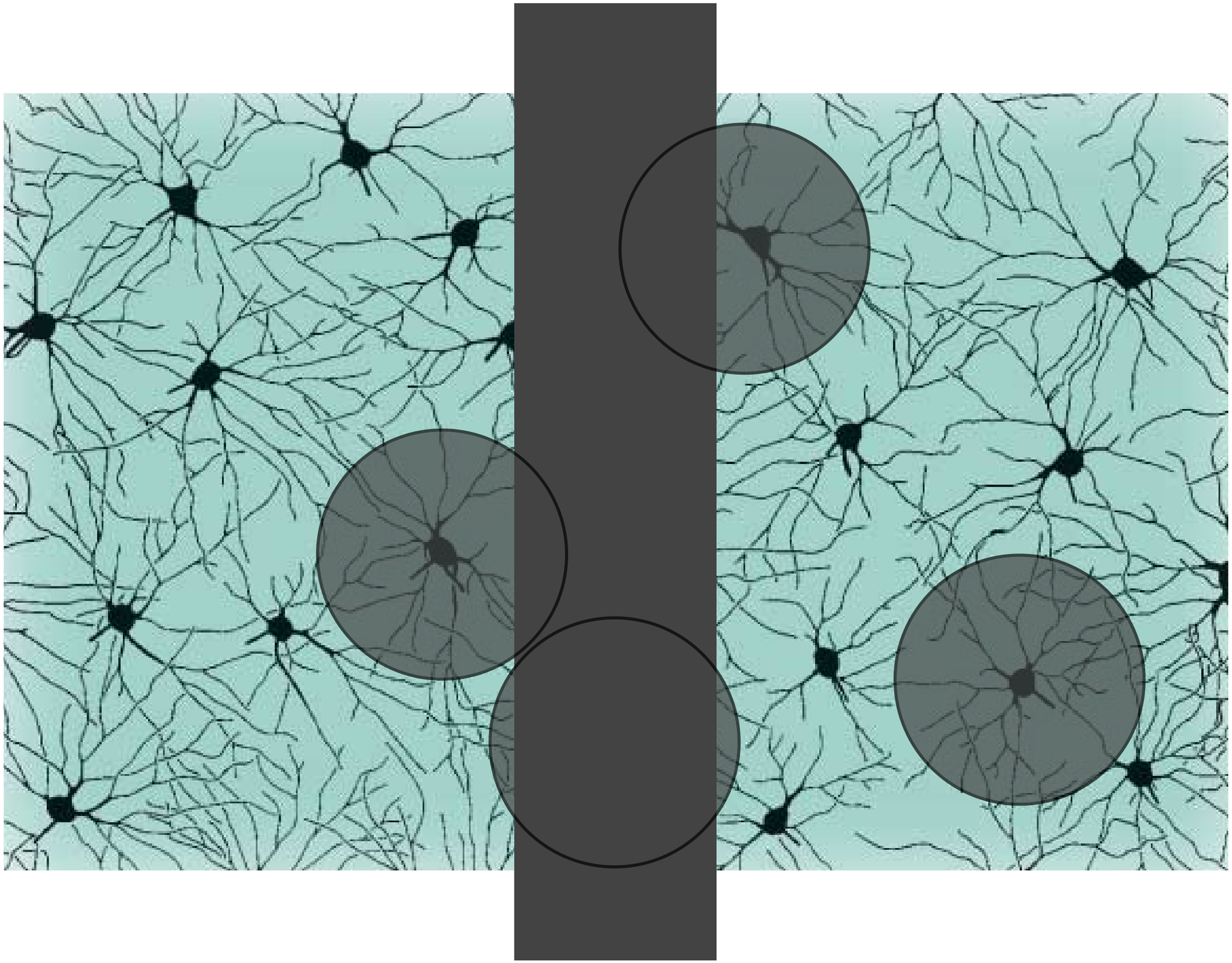
Berry and Meister 1999



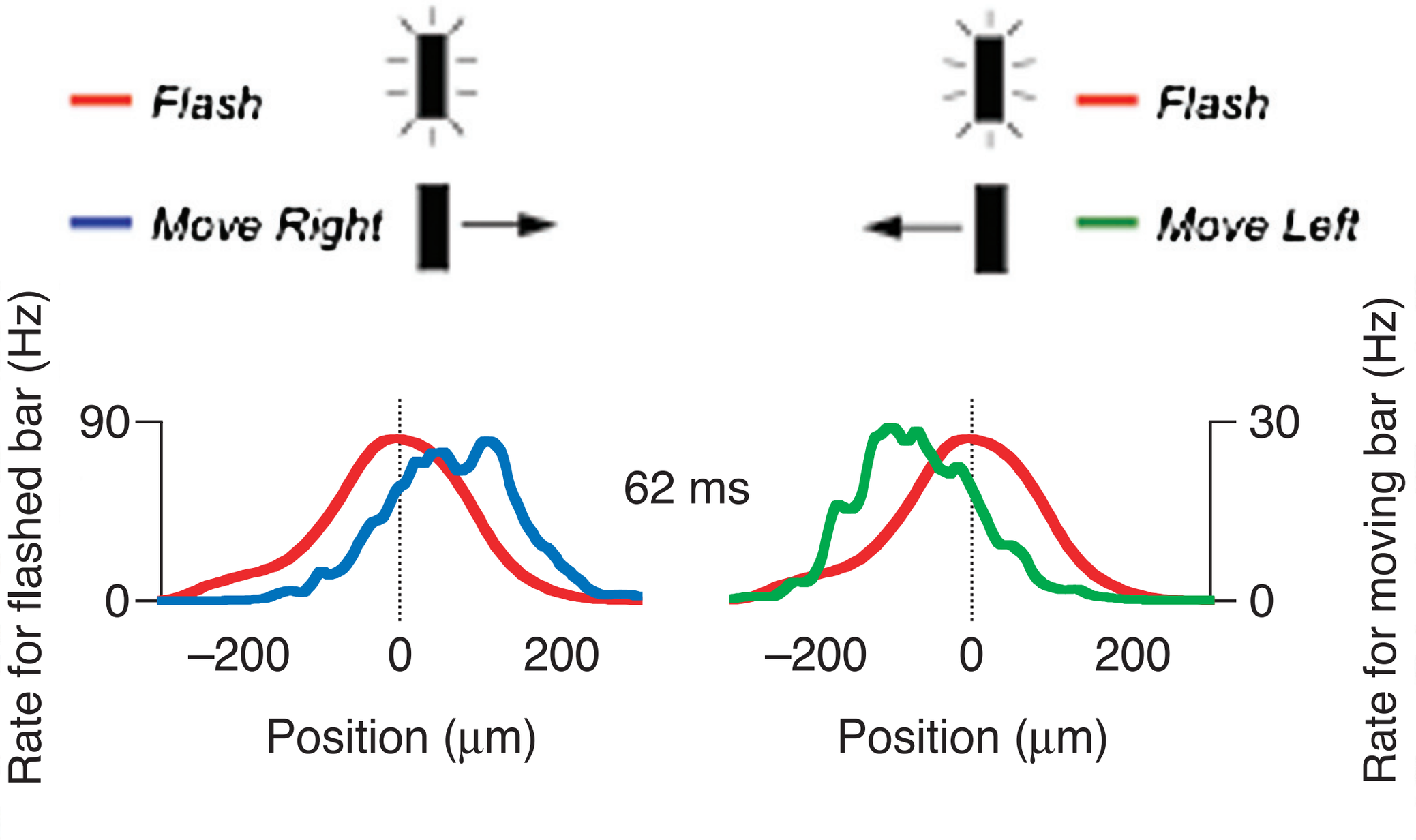
Motion anticipation in the vertebrate retina:



Berry and Meister 1999

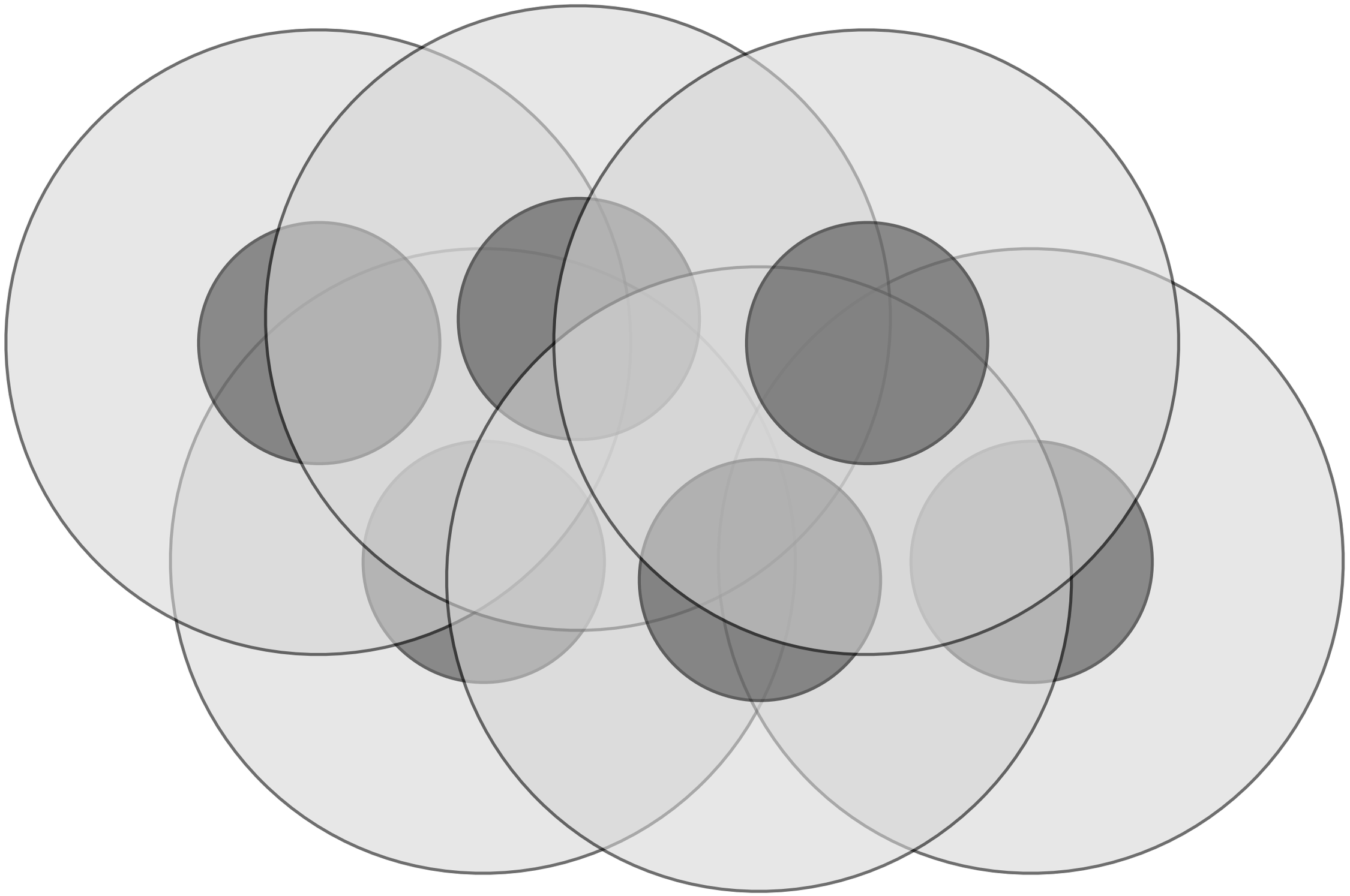


Motion anticipation in the vertebrate retina:



Berry and Meister 1999

This doesn't work with simple linear filters:



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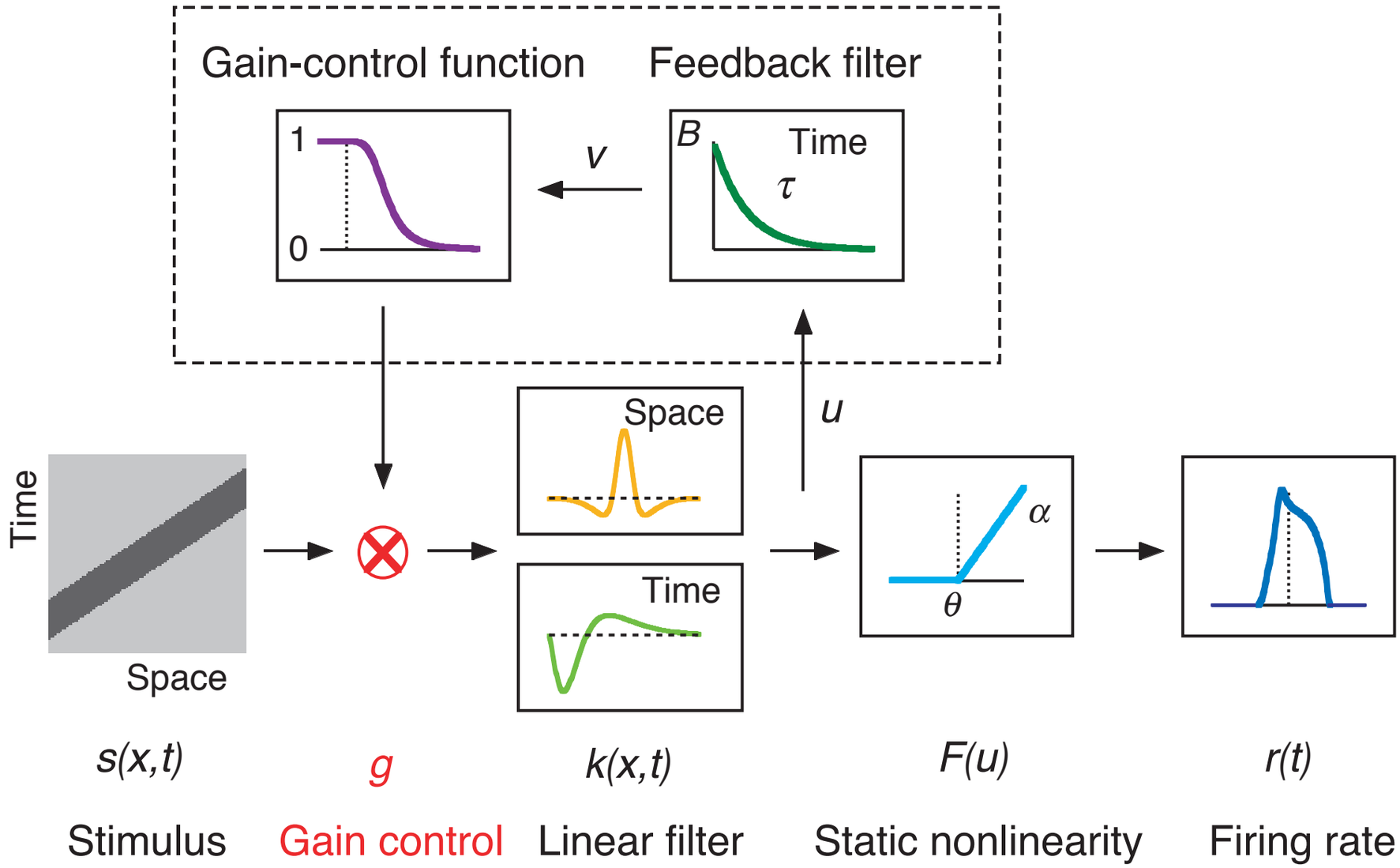
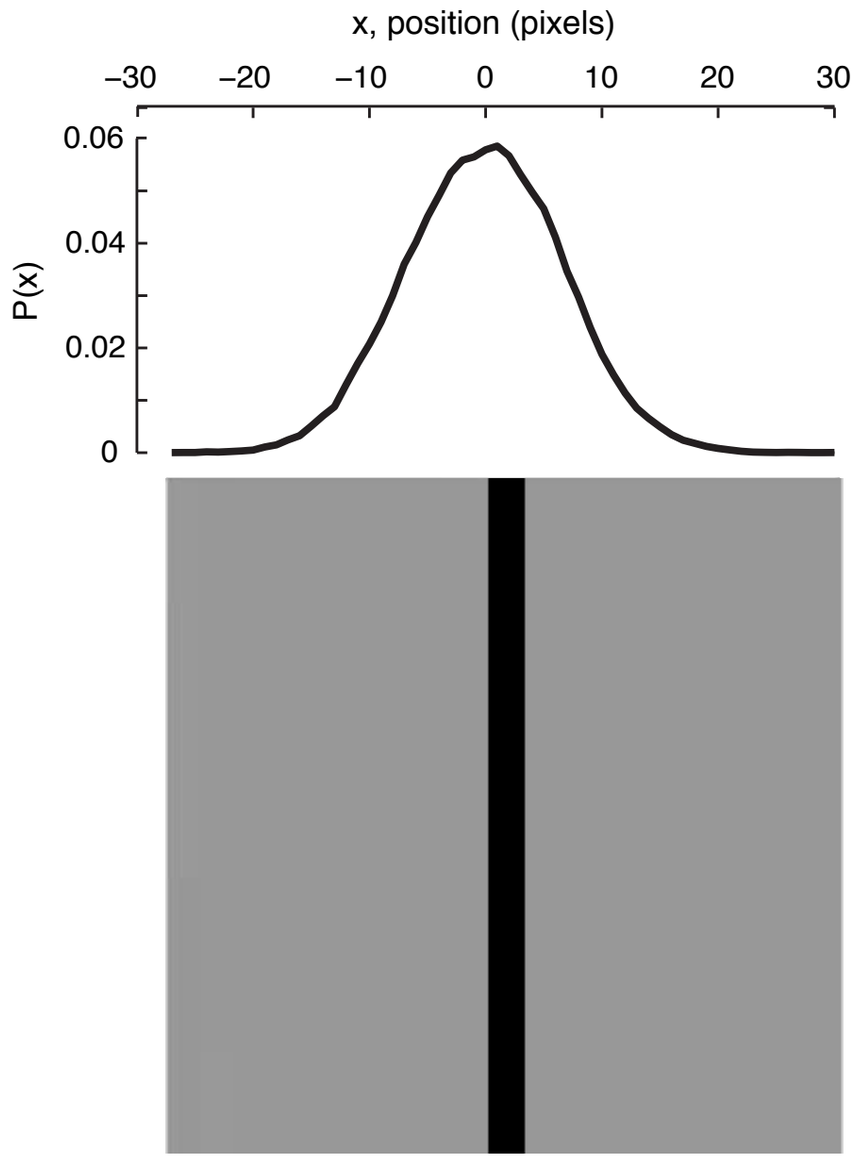
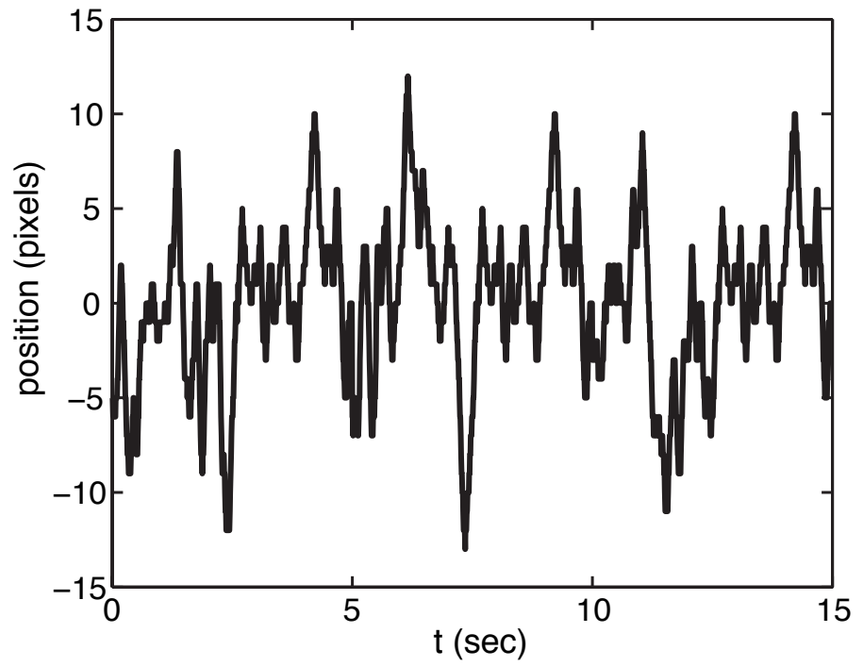


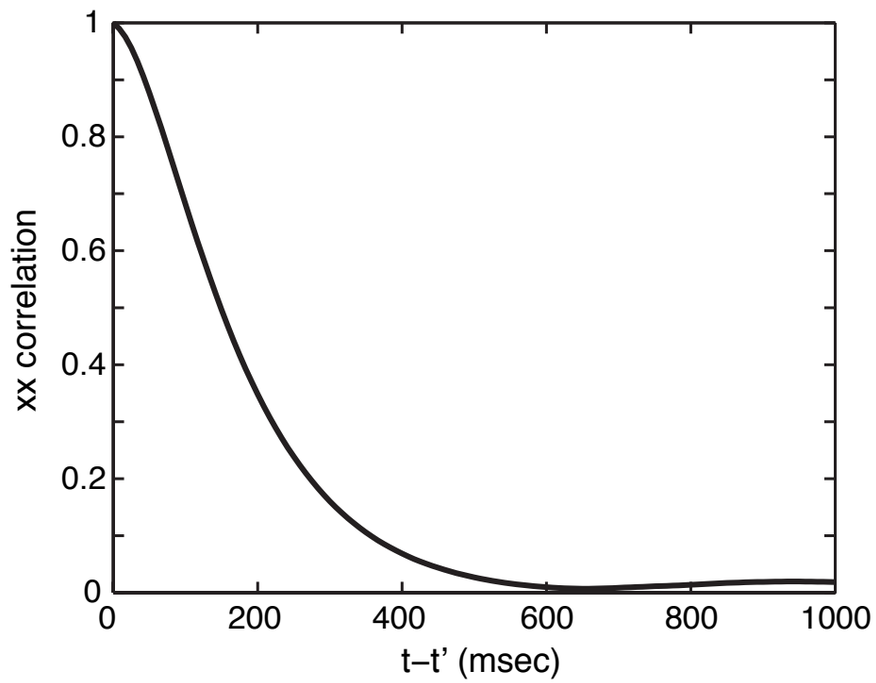
Berry and Meister 1999

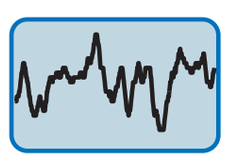
A more complex bar stimulus:



$$\frac{dv}{dt} = -\frac{v}{\tau} + D^{1/2}\Gamma(t) - \omega_0^2 x$$

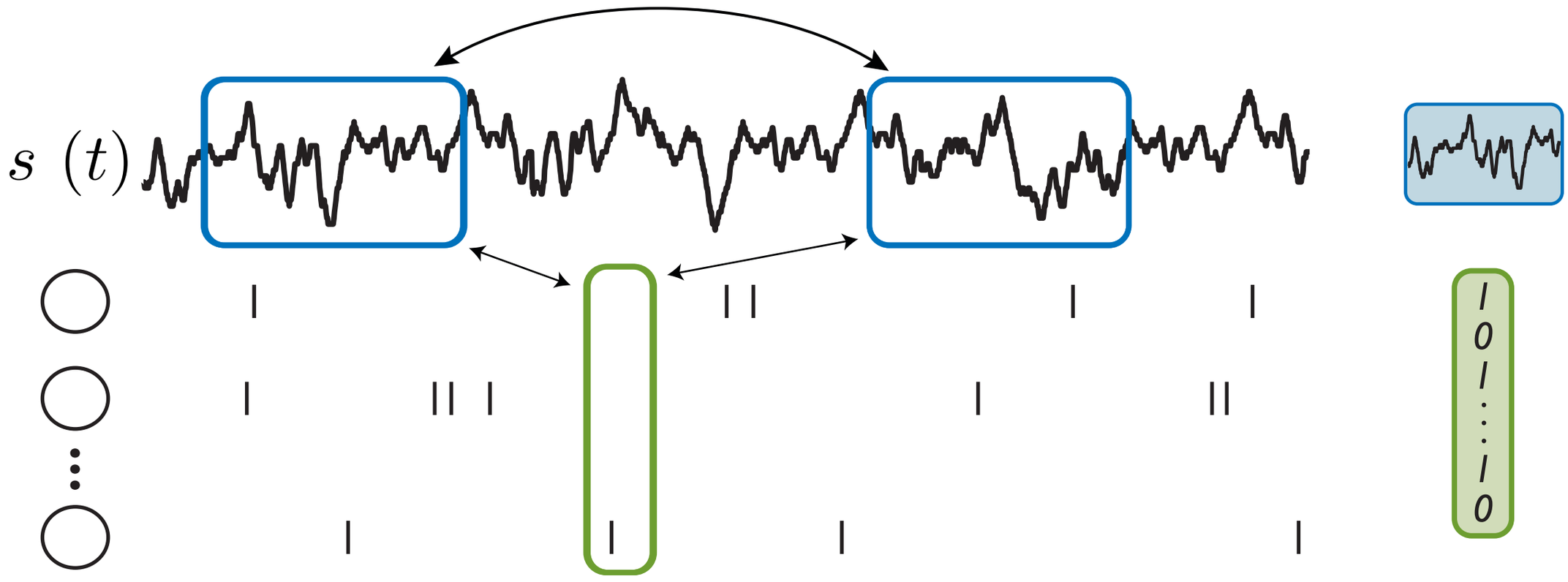




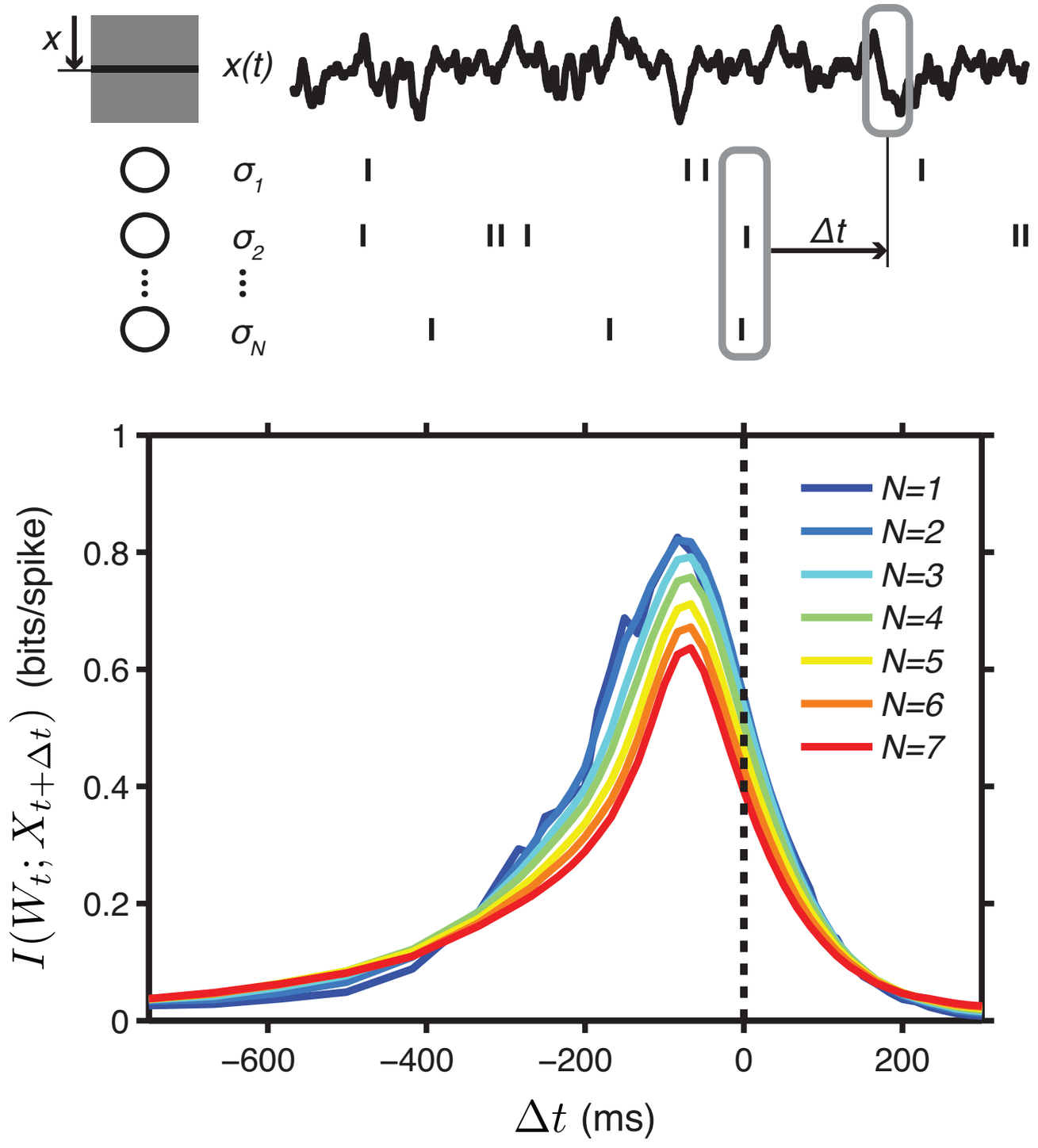


Schematic of our calculations:

$$I(\text{past};\text{future}) = S(\text{future}) - S(\text{future}|\text{past})$$



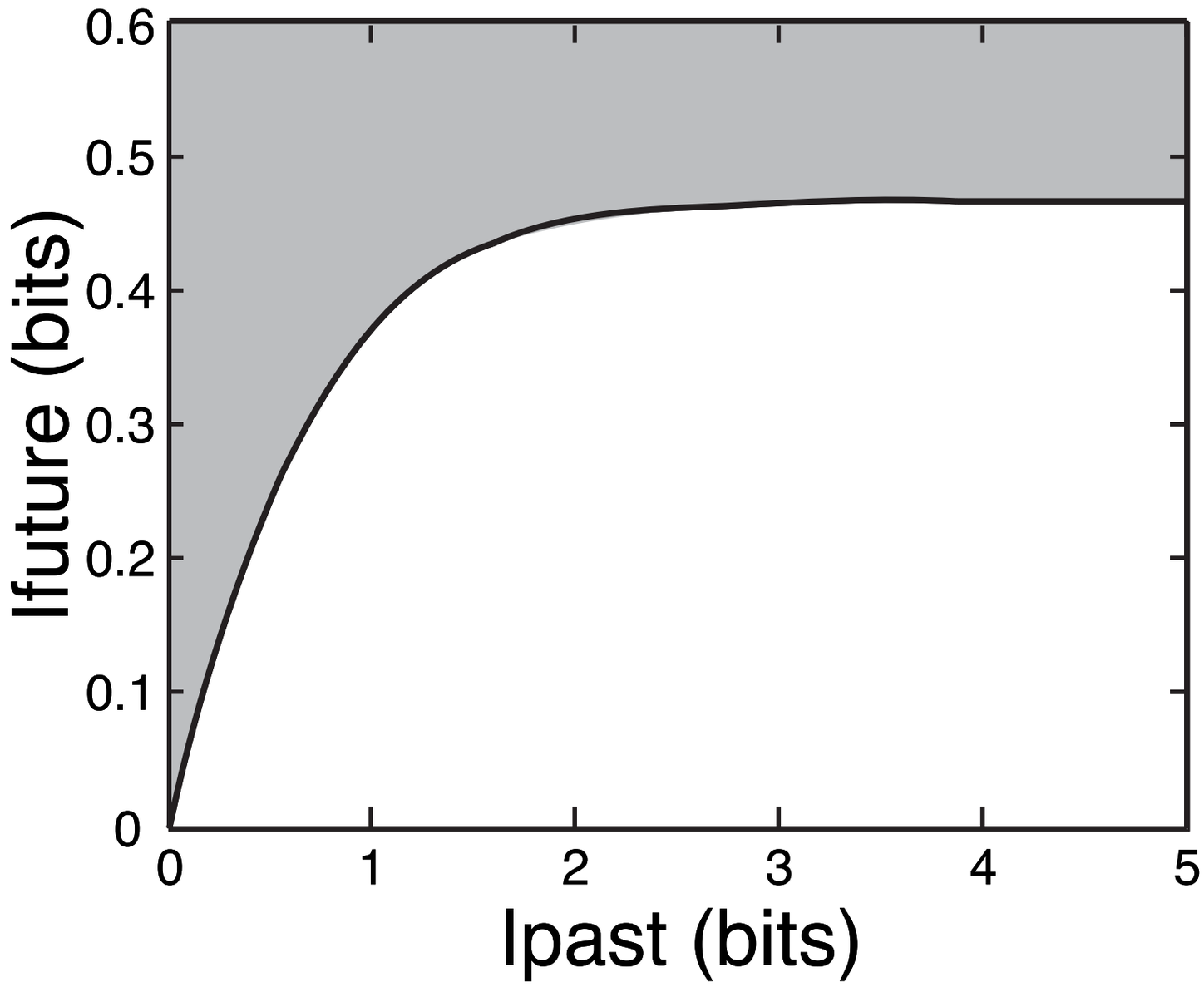
Computing information about bar position:

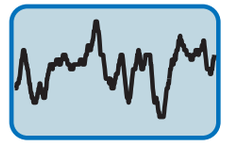


Palmer et al. PNAS (2015)

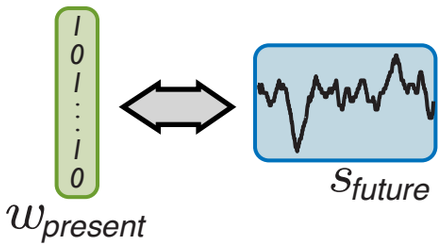
Optimal compression:

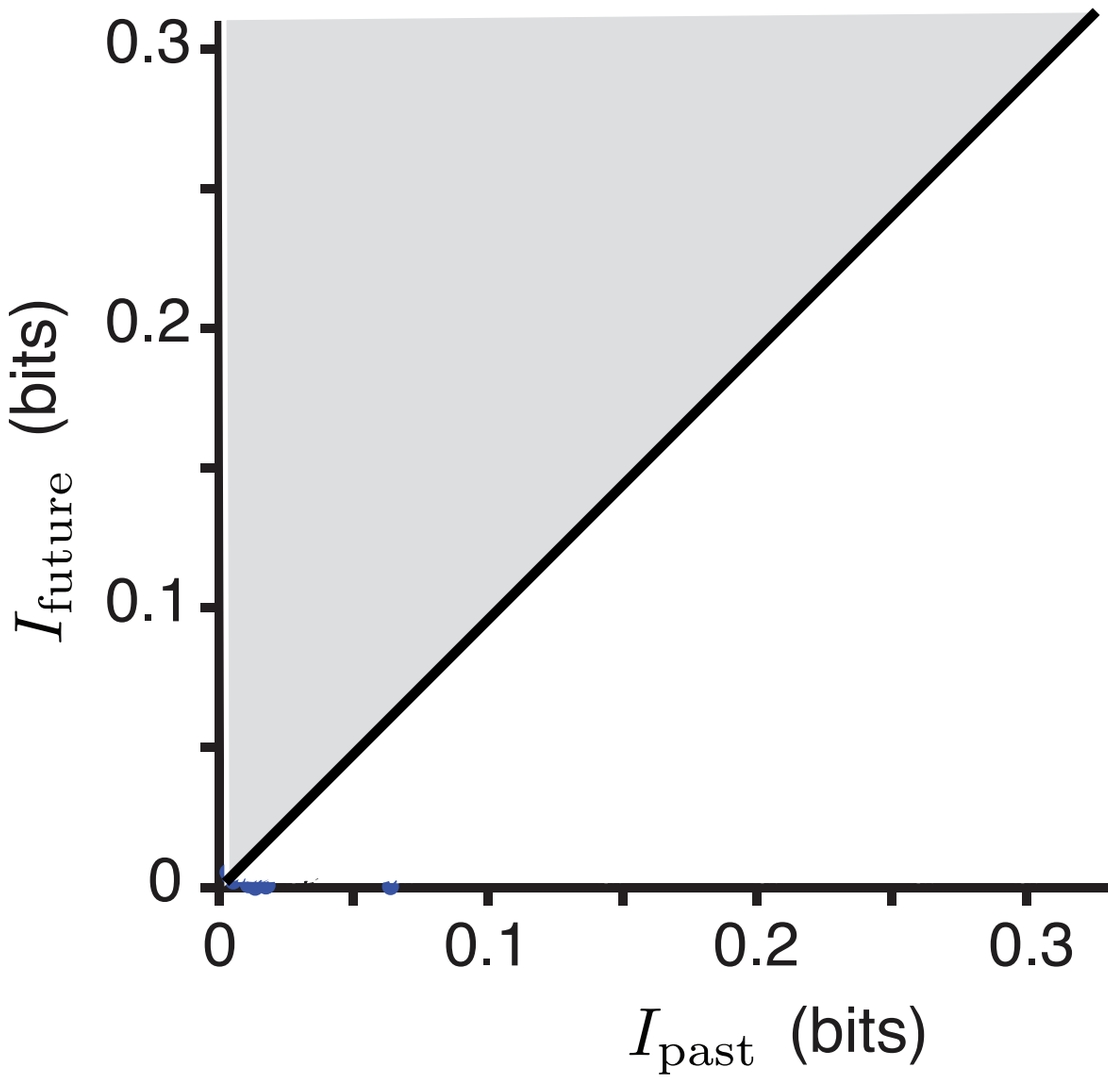
$$L = I(X_{\text{present}}; \vec{S}_{\text{past}}) - \beta I(X_{\text{present}}; \vec{S}_{\text{future}})$$

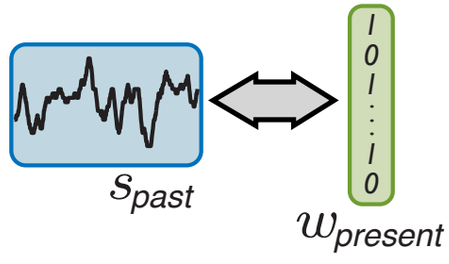




Spiking patterns sit close to the bound:







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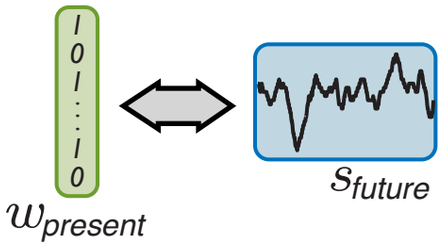

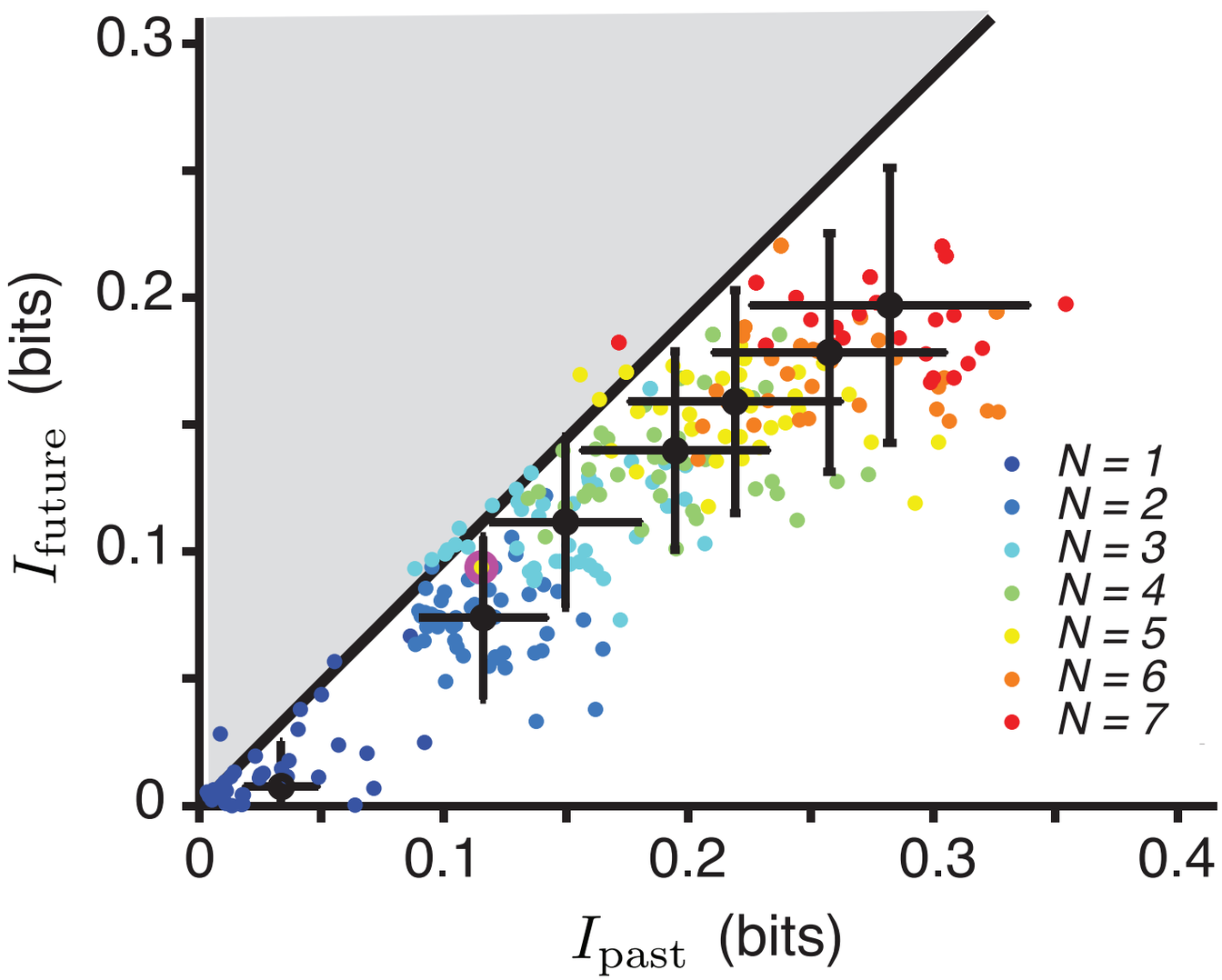

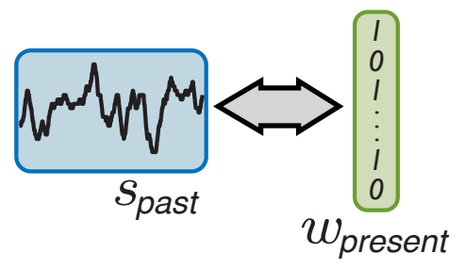

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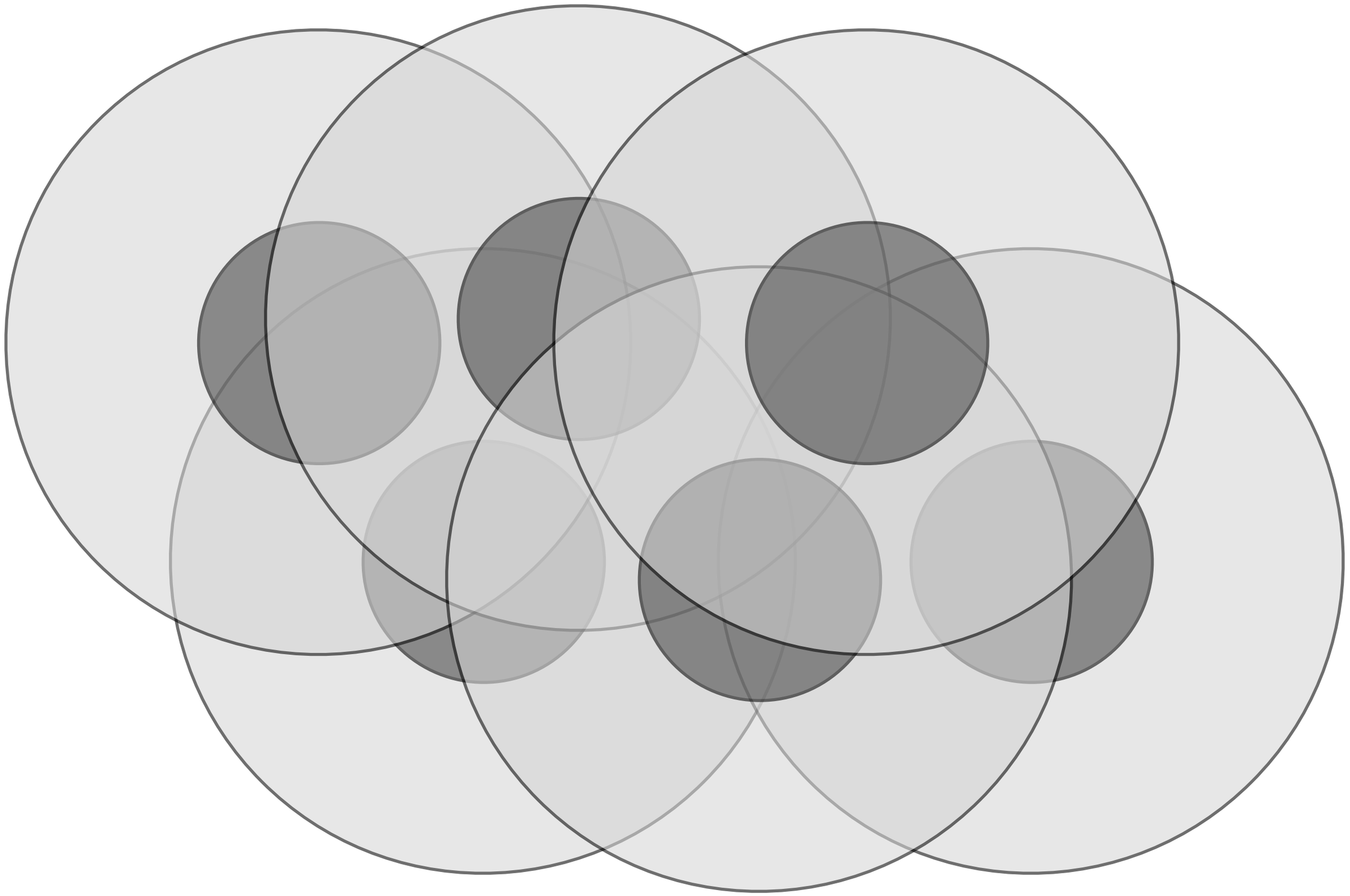

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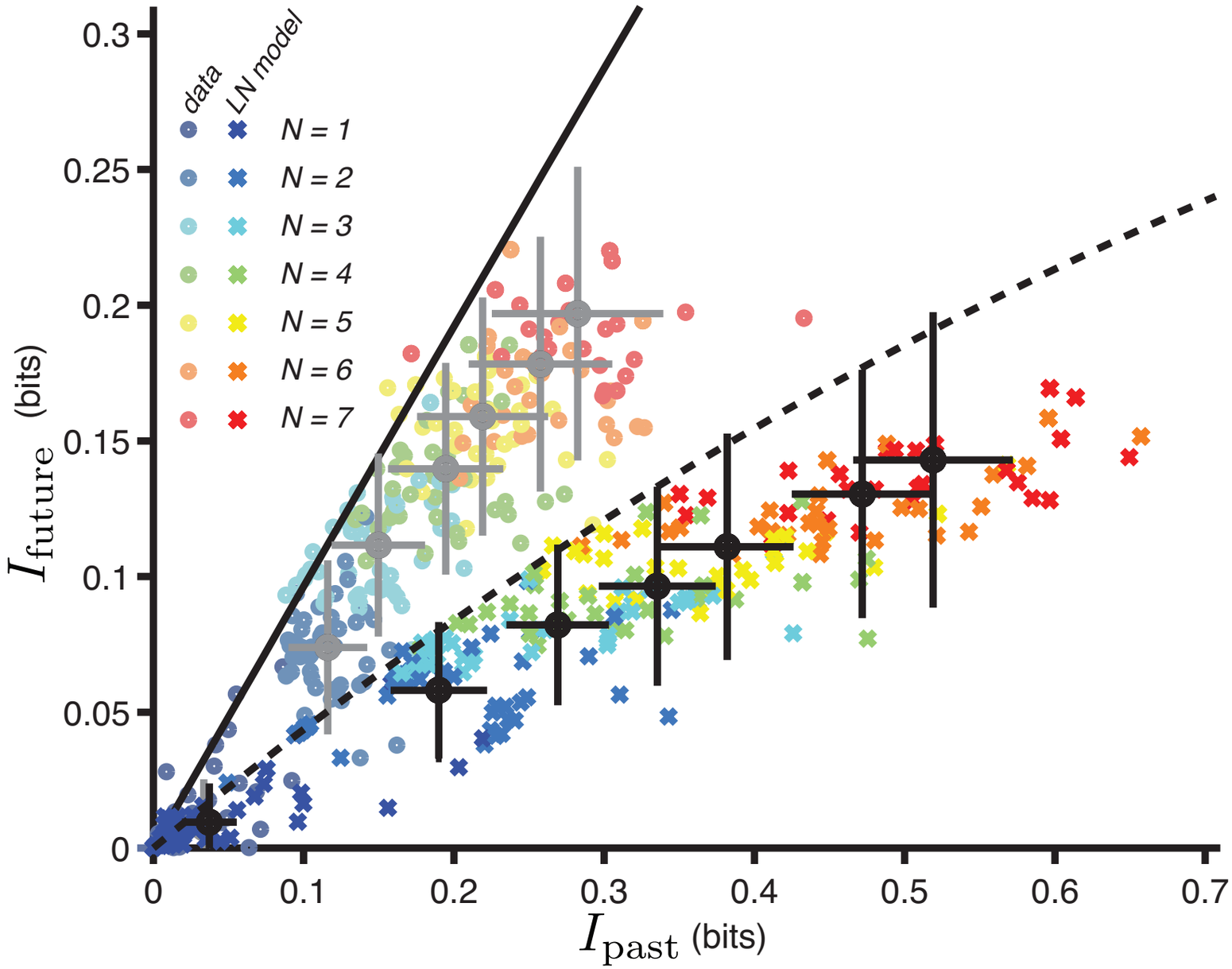
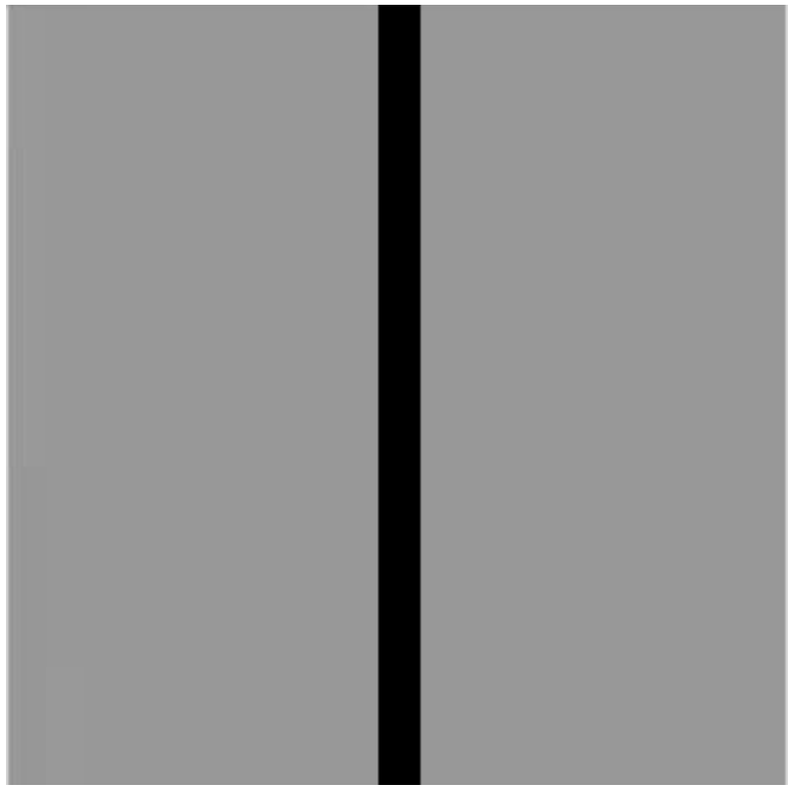


Palmer et al. PNAS (2015)

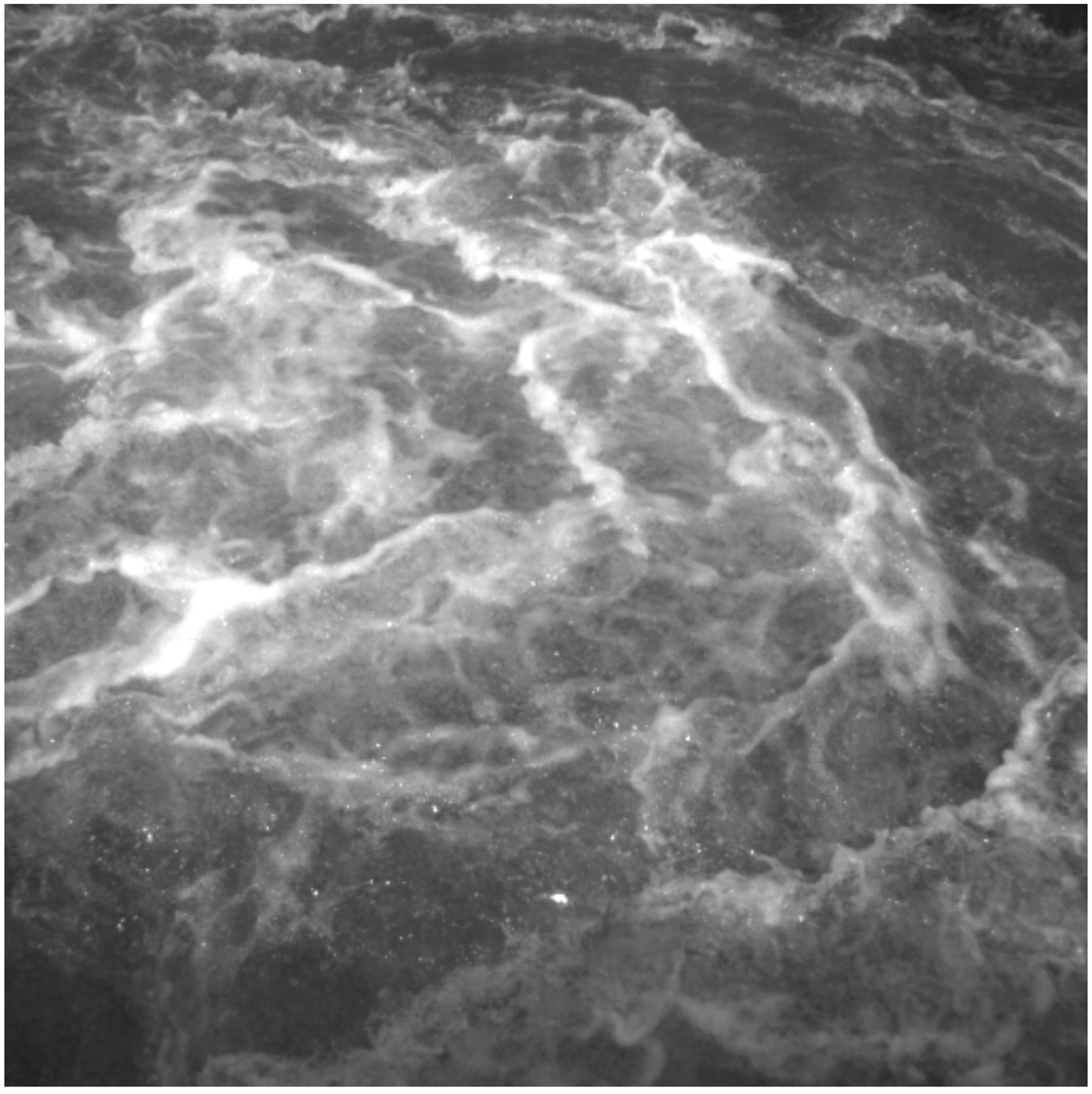
Towards more natural motion stimuli:



speculative interlude

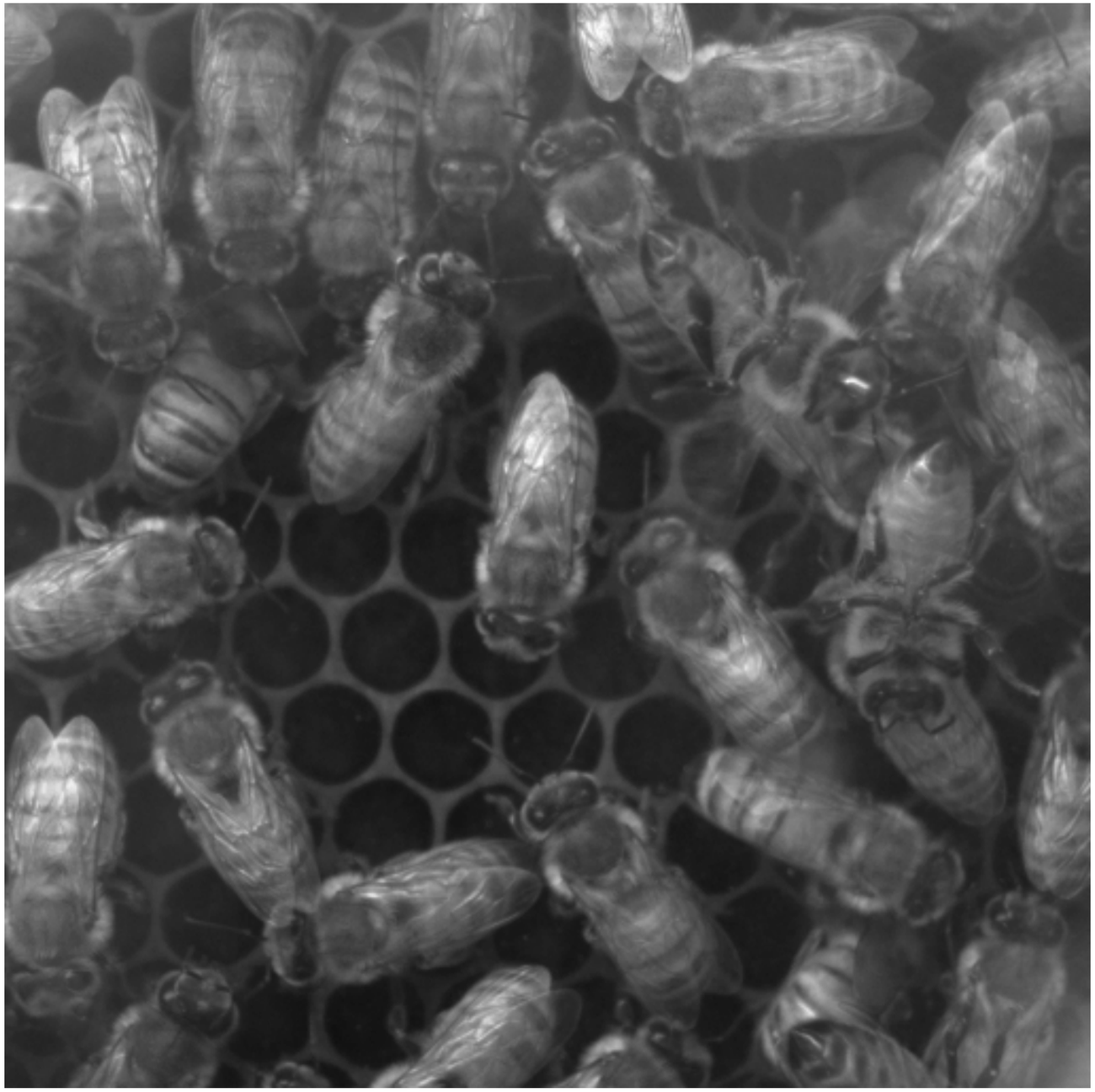
Filming a natural scene can be dull:

Chicago Motion Database: water

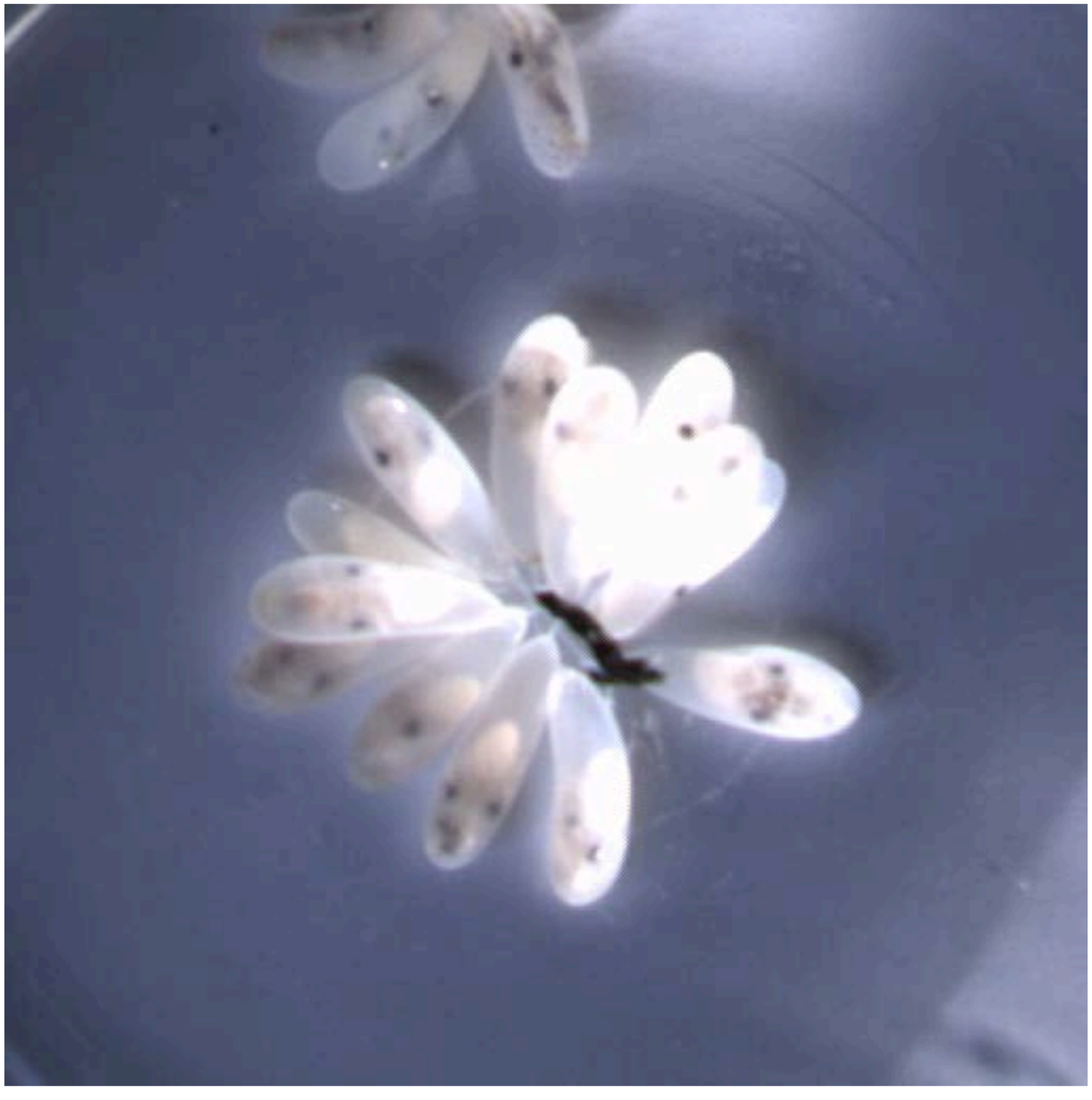


Chicago Motion Database: insects

Chicago Motion Database: insects

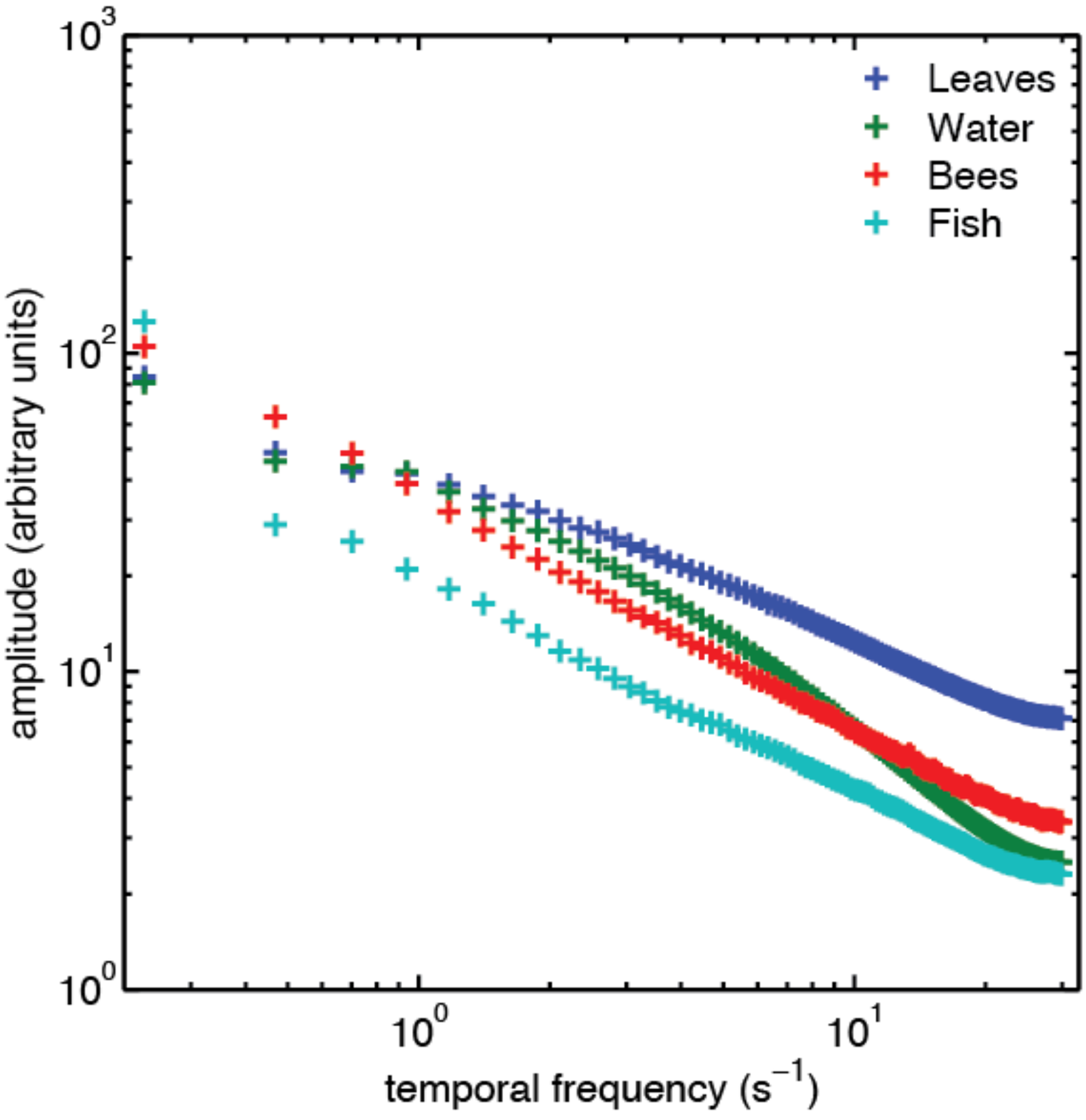


Chicago Motion Database: small predators



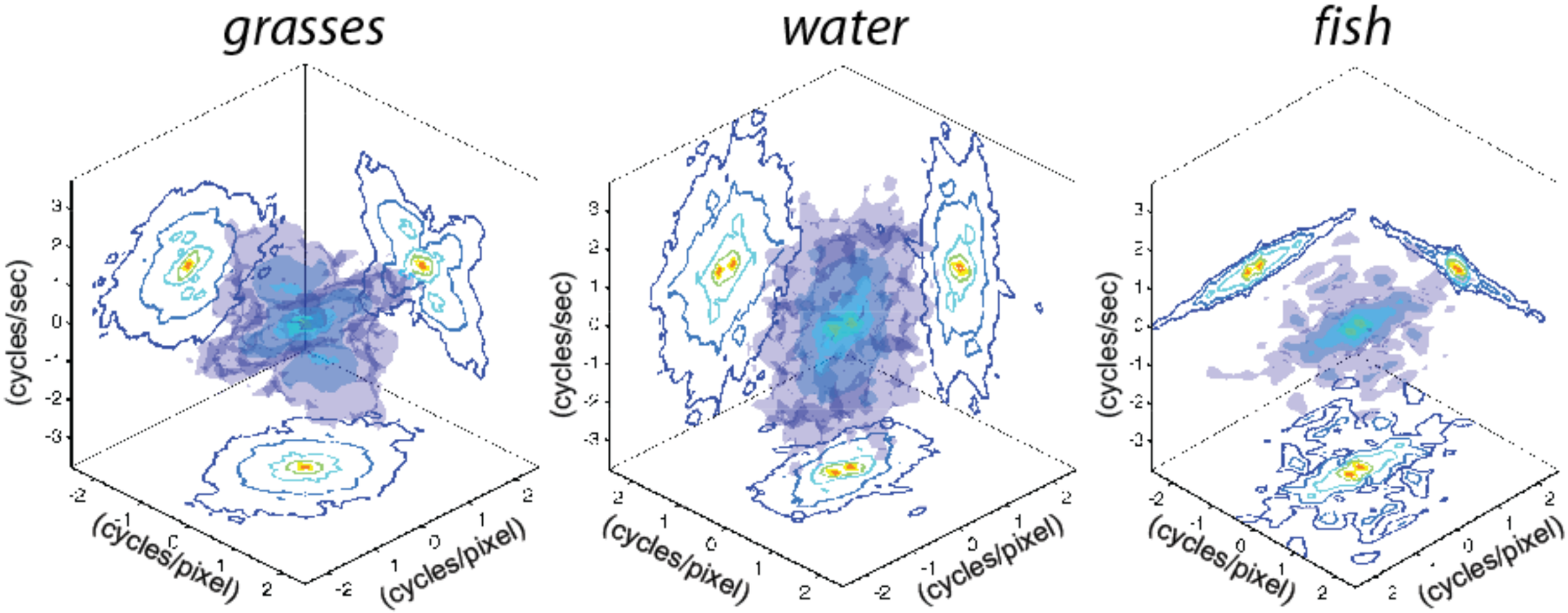
Ragsdale Lab

Temporal power spectra:



Jared Salisbury

3D power spectra:



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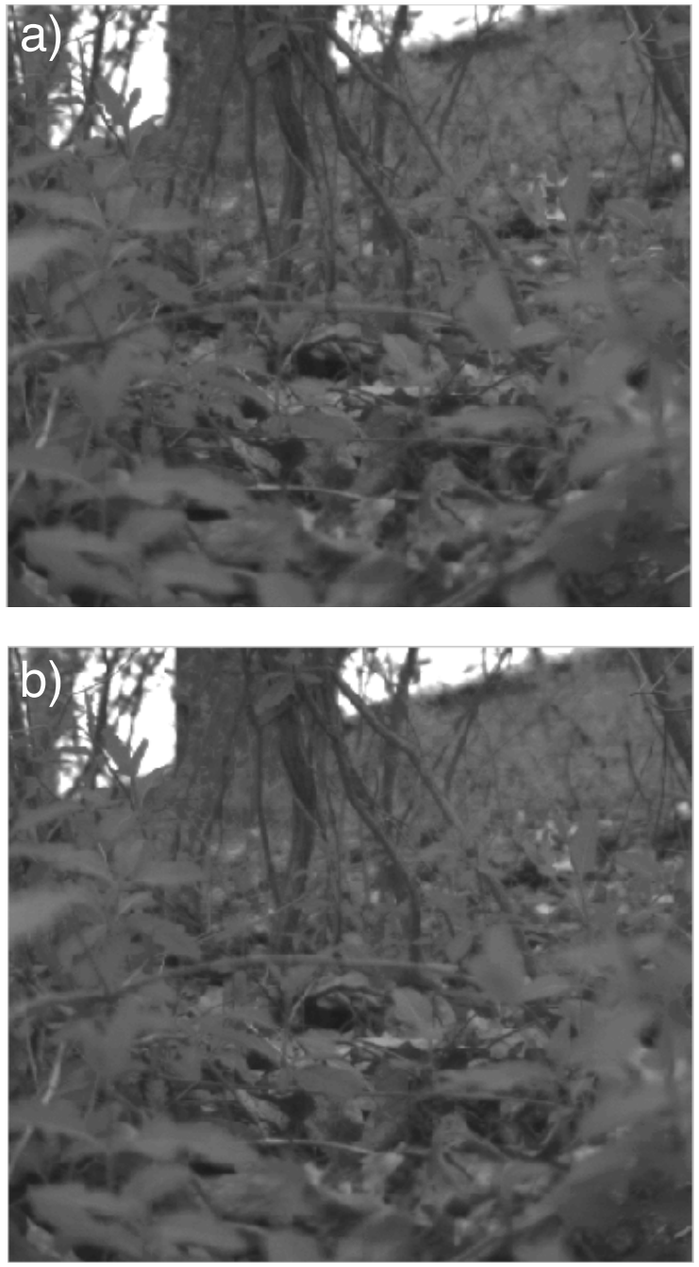
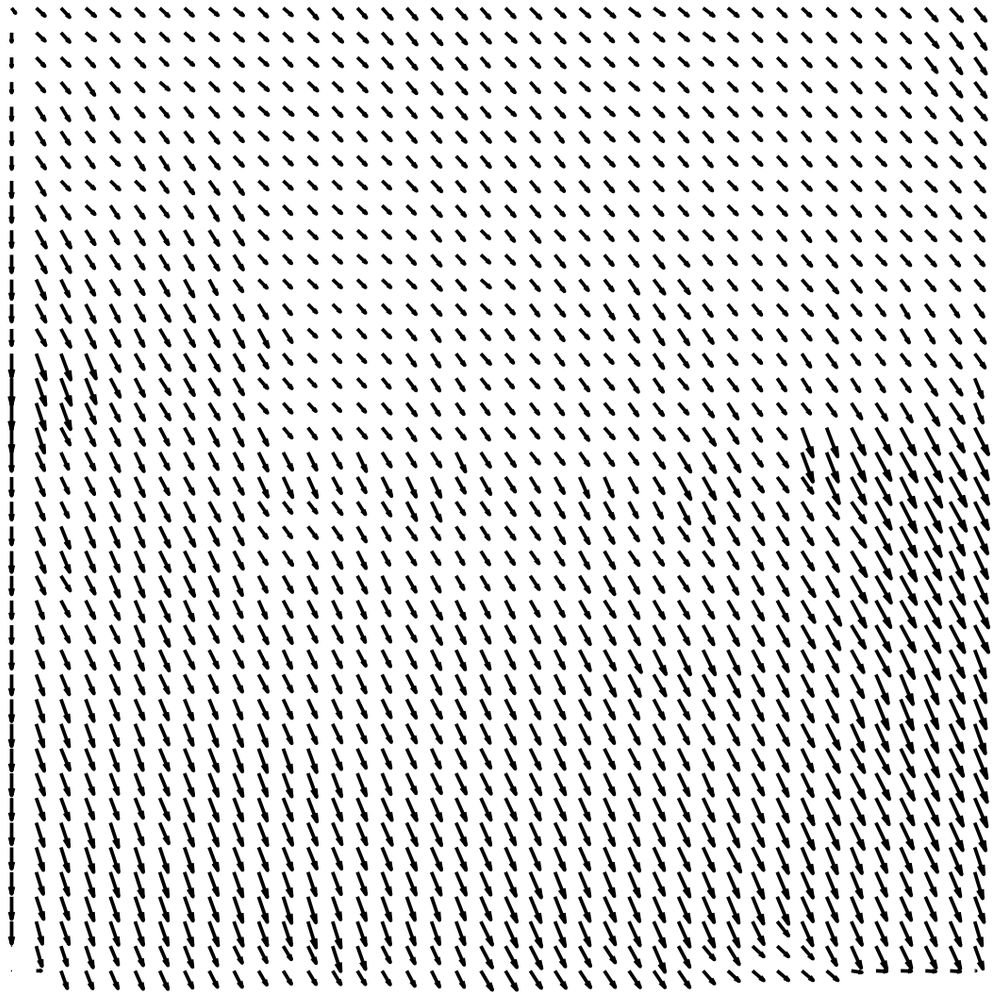
Flow fields from natural movies:





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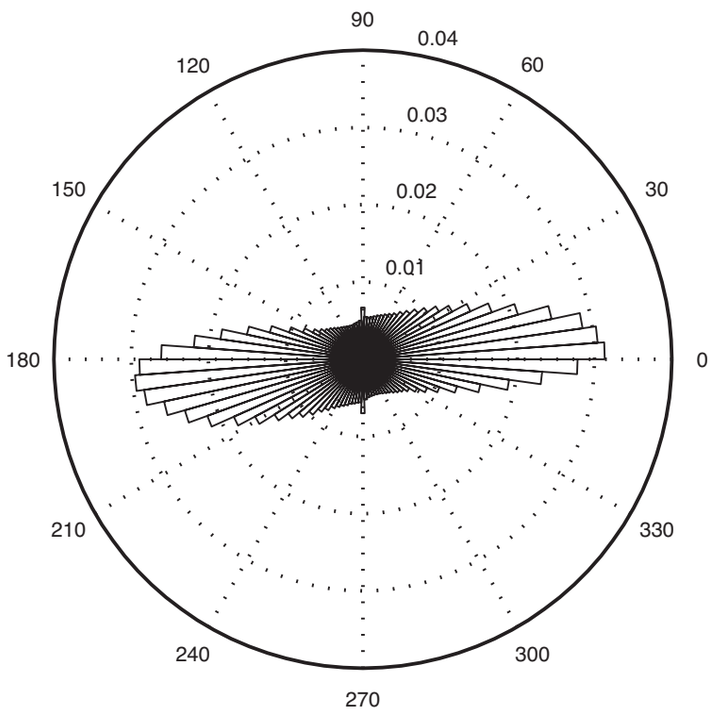
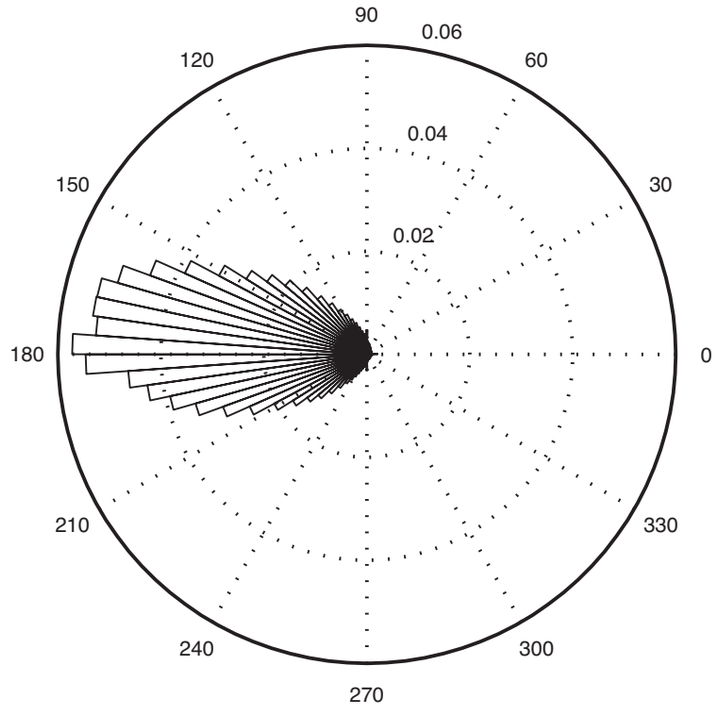
Flow direction histograms:

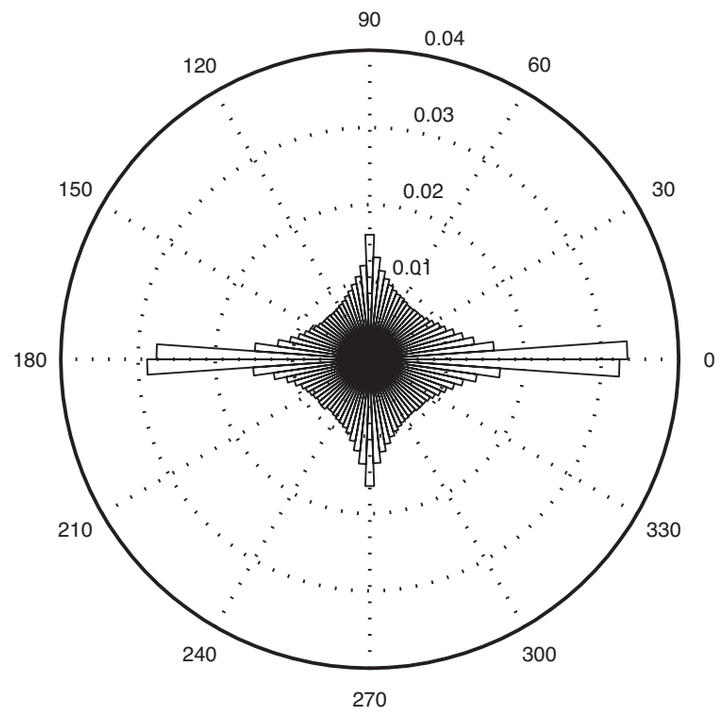
grasses



water



fish



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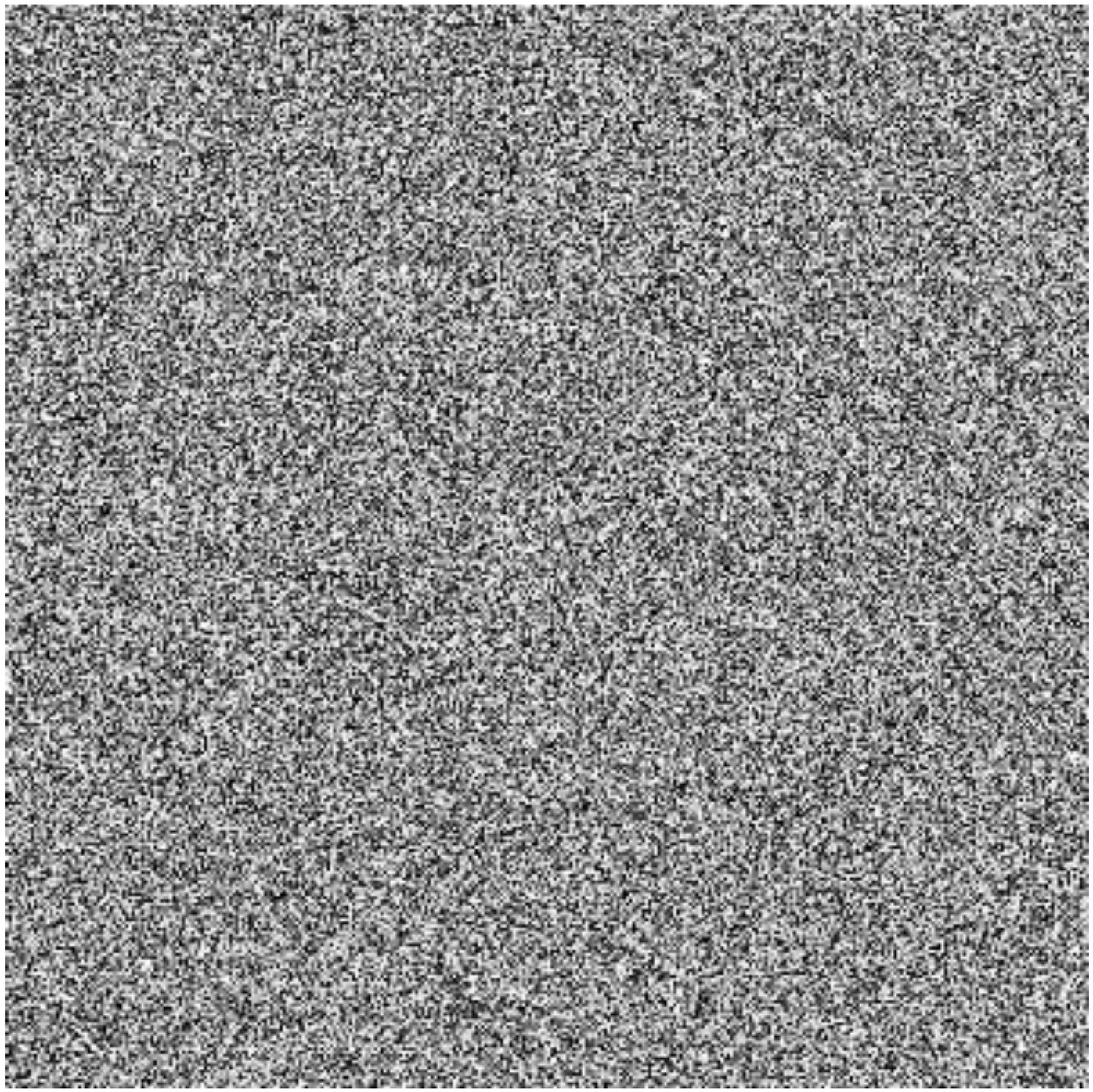
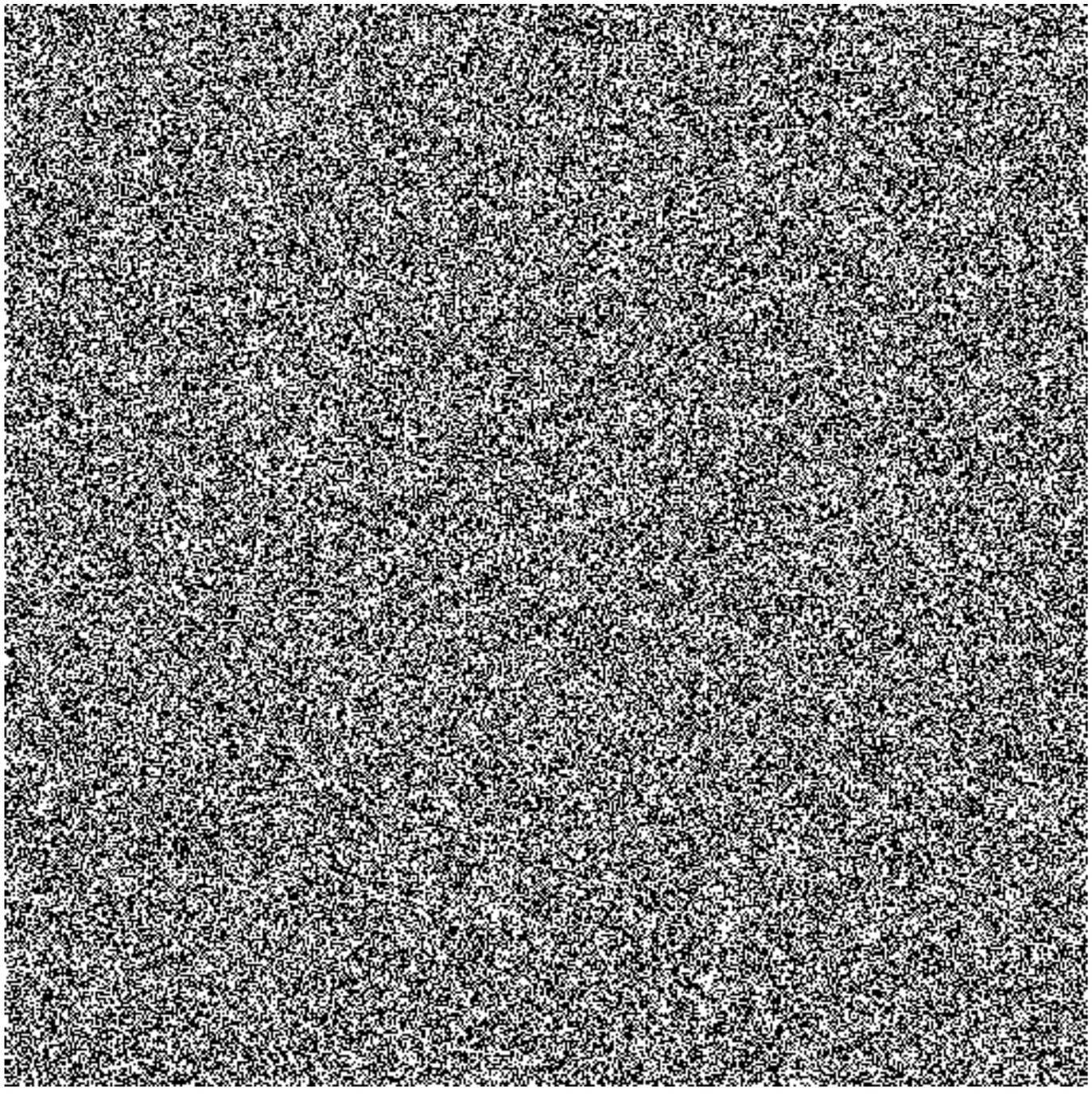
Analyzing local flow:

Analyzing local flow:

Removing spatial correlations in each frame:



...and for animal motion:



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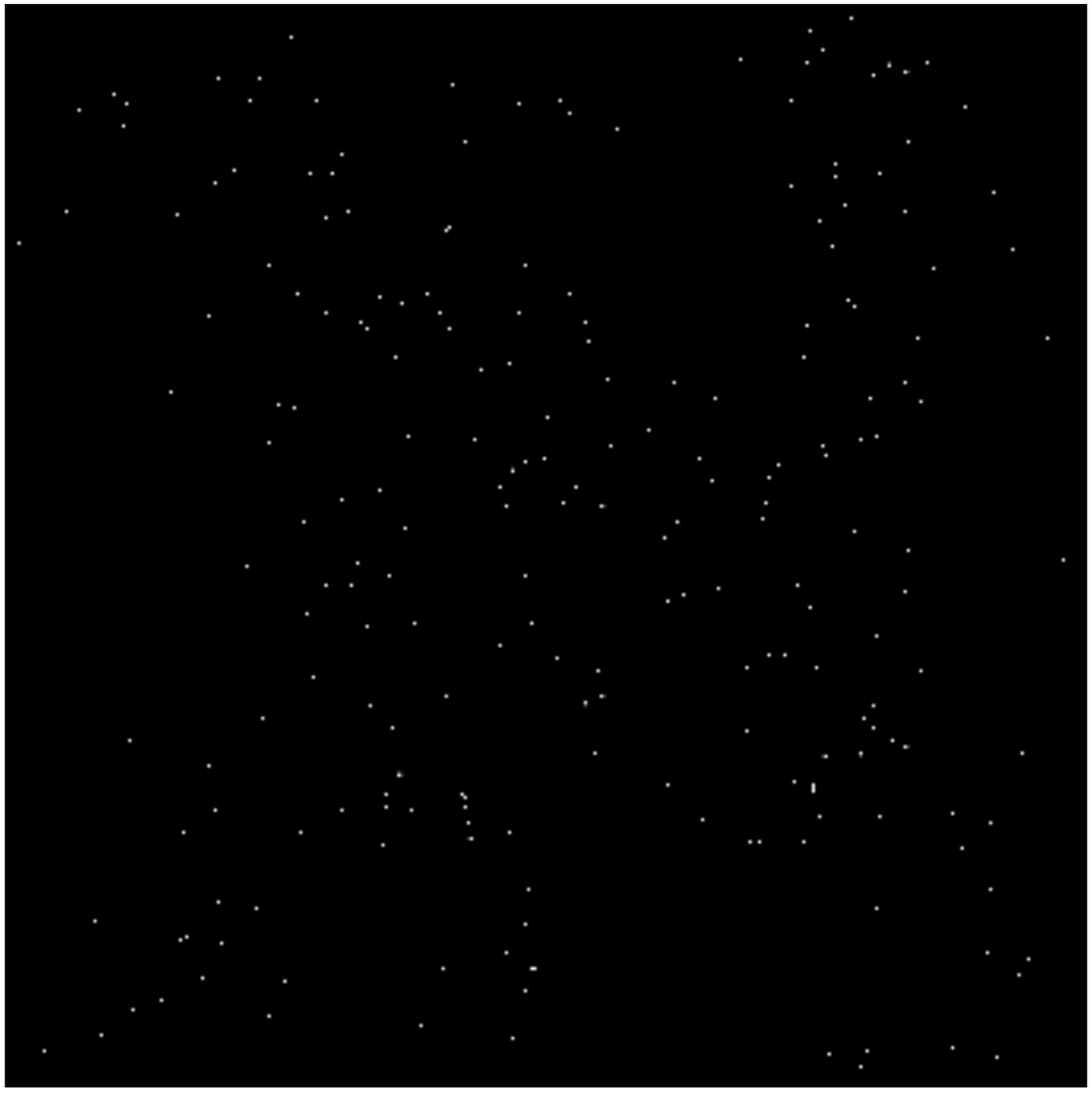
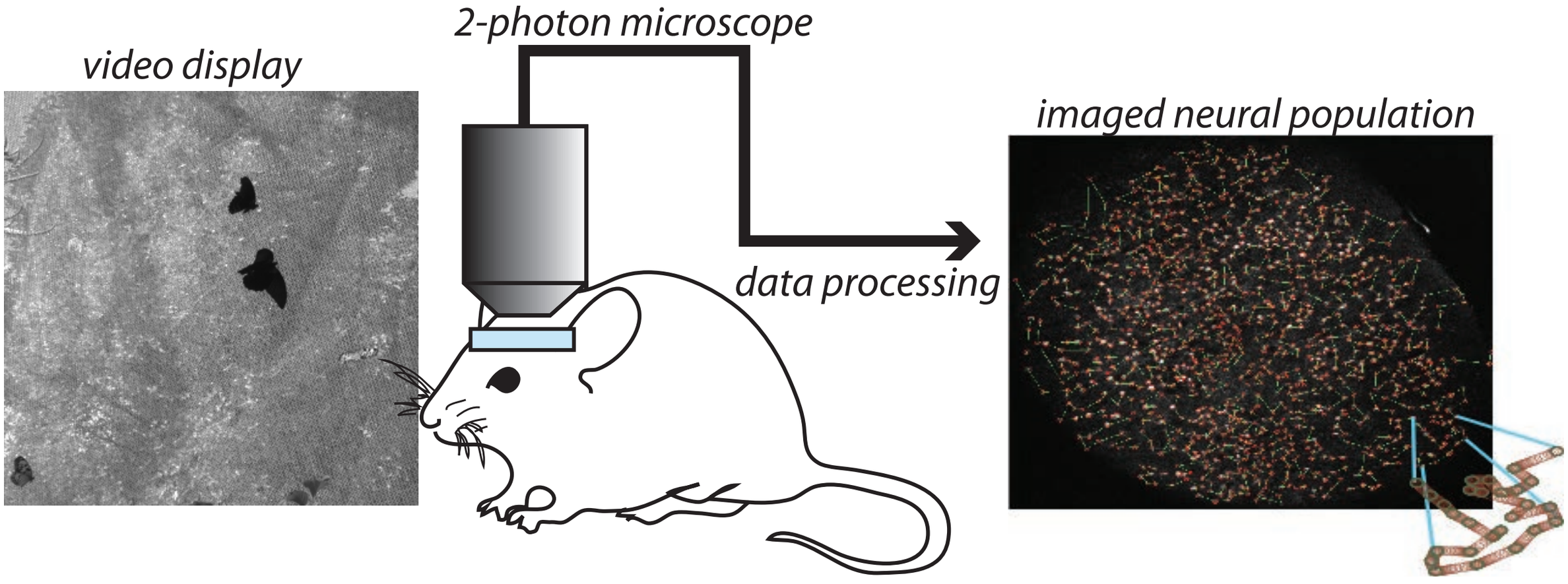
‘Particle’ tracing using flow fields:



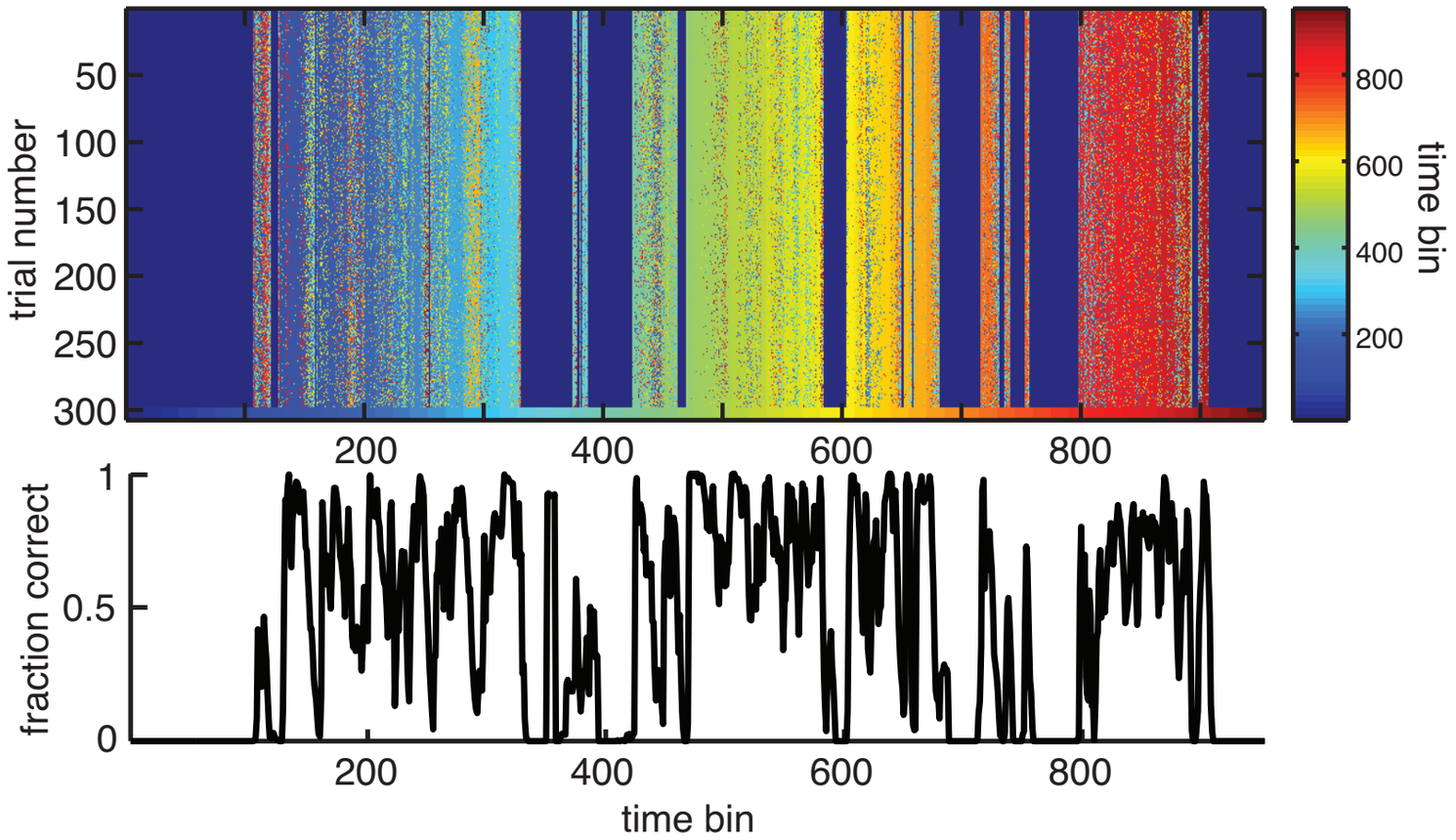
speculative interlude

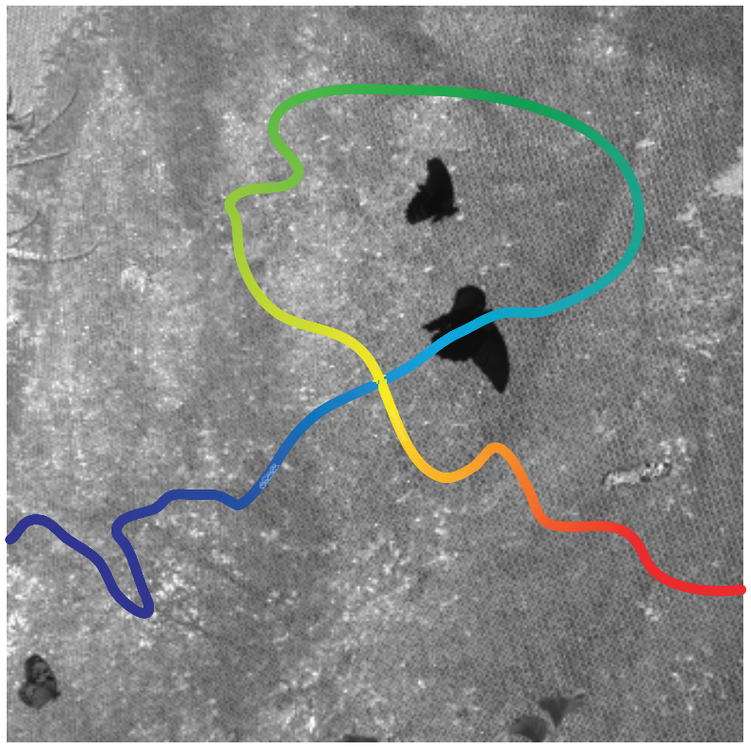
Recording from visual cortex during natural movie presentation:



MacLean and Palmer Labs

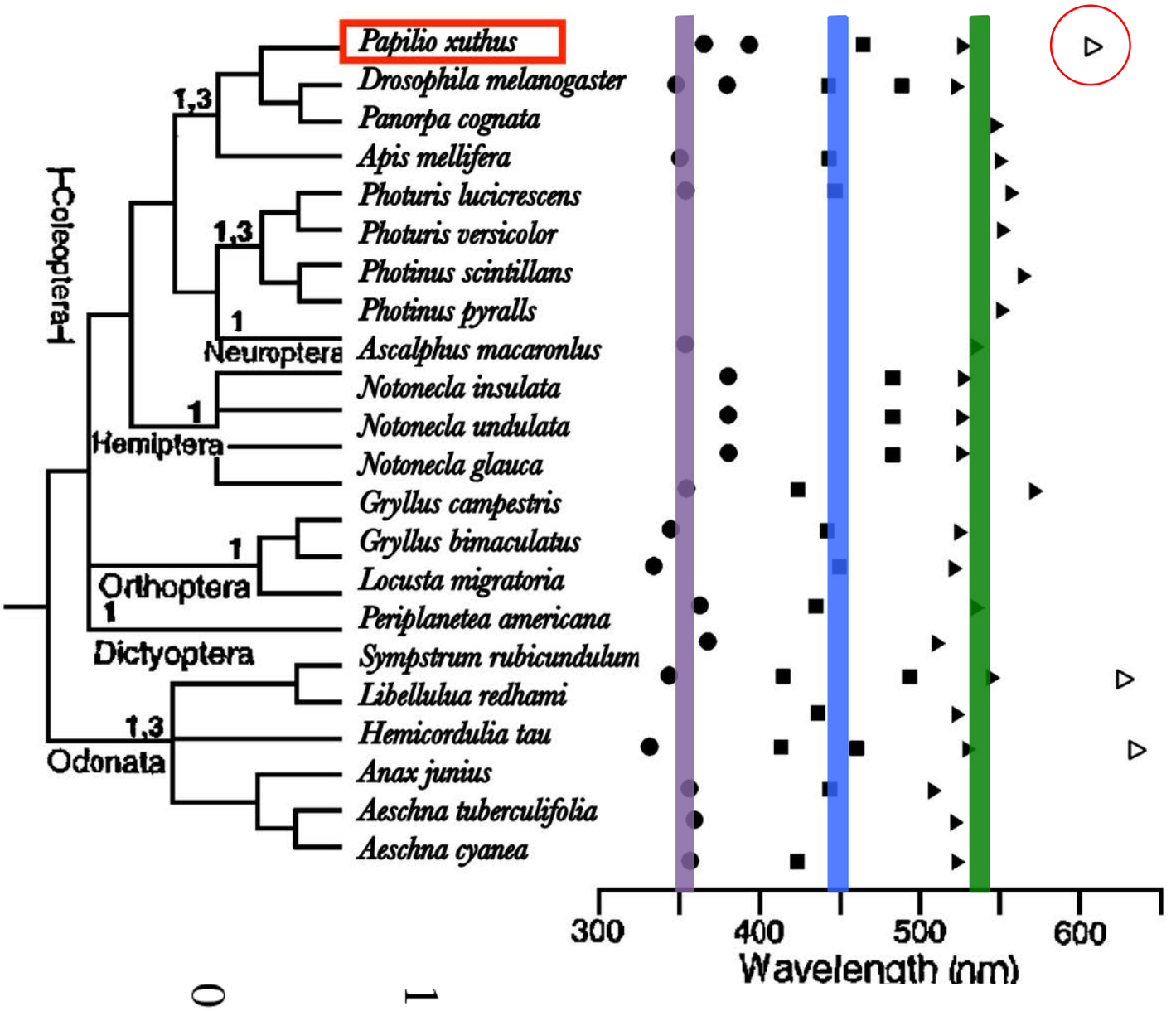
Decoding time in the movie from retinal data (using deep neural nets):

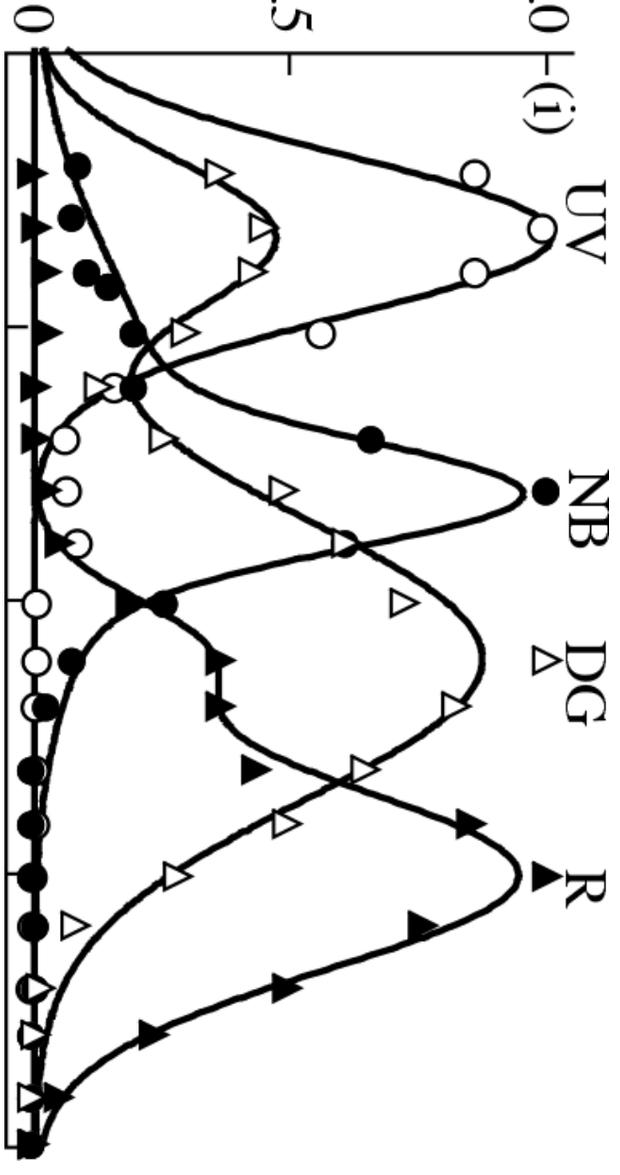




D Schwab and SEP

REALLY speculative interlude


Papilio xuthus
Drosophila melanogaster
Panorpa cognata
Apis mellifera
Photuris lucicrescens
Photuris versicolor
Photinus scintillans
Photinus pyralls
Ascalphus macaronlus
Notonecla insulata
Notonecla undulata
Notonecla glauca
Gryllus campestris
Gryllus bimaculatus
Locusta migratoria
Periplanetea americana
Sympstrum rubicundulum
Libellulua redhami
Hemicordulia tau
Anax junius
Aeschna tuberculifolia
Aeschna cyanea
1,3
1,3
1
1
1
1
1,3
Coleoptera
Neuroptera
Hemiptera
Orthoptera
Dictyoptera
Odonata
300
400
500
600
Wavelength (nm)


1.0
0.5
0
(i)
UV
NB
DG
R