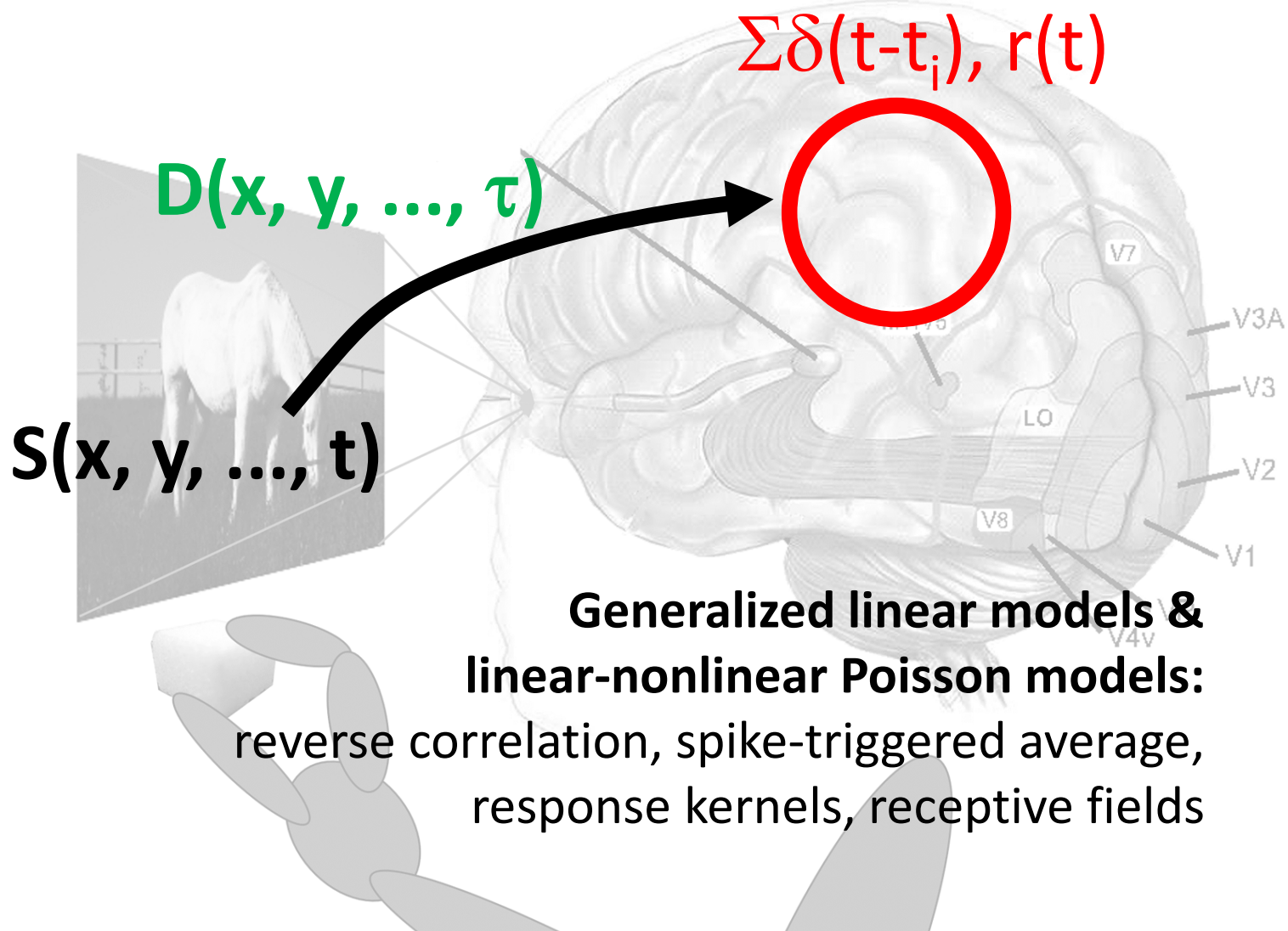
Lecture 3:

Neuronal encoding:

RFs, LNPs, GLMs, RC, and STA(*)

(*) Mny abbrv. cnsidbl. reduce readabl. txt.

Forward: Modelling neural responses to dynamical stimuli...

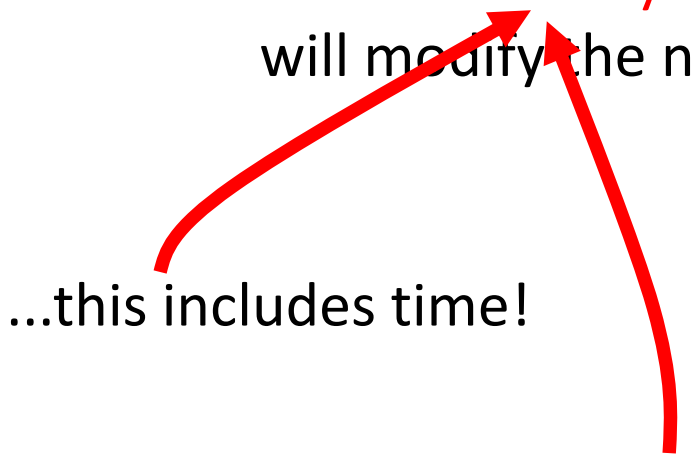


Generalized linear models & linear-nonlinear Poisson models:
reverse correlation, spike-triggered average, response kernels, receptive fields

Backward - solving the inverse problem: What the **** do neurons care for?

Determine receptive fields (RFs)!

RF: Part of the sensory space in which a stimulus will modify the neuron's response.

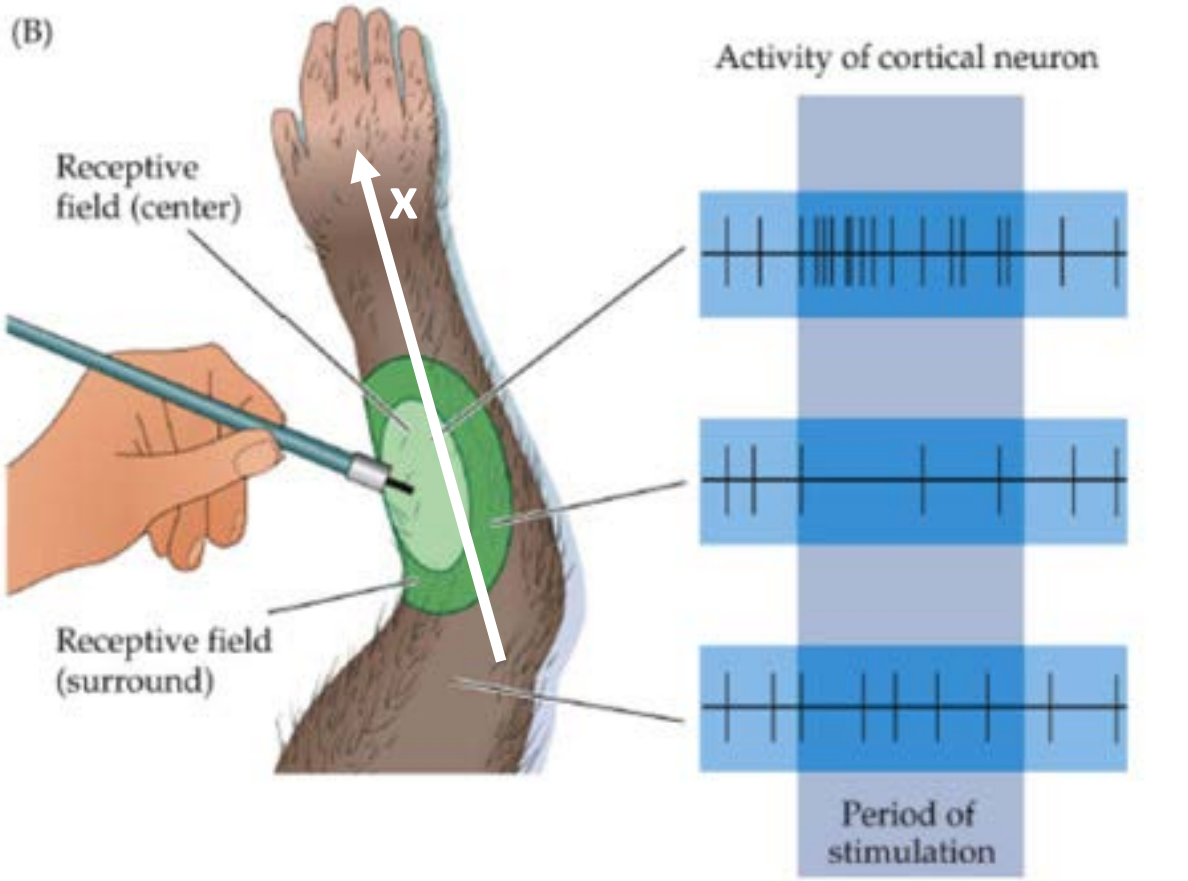


...this includes time!

...and more abstract representations such as orientation, pressure, frequency!

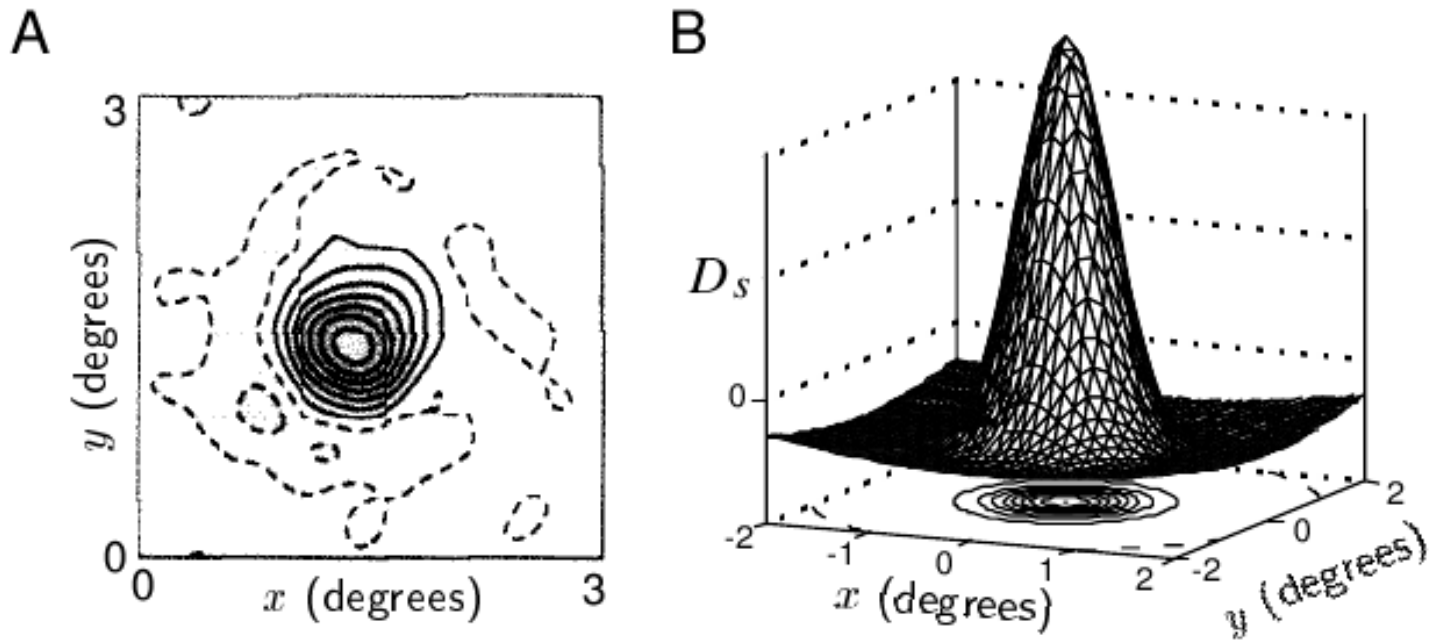
Examples

Tactile receptive fields

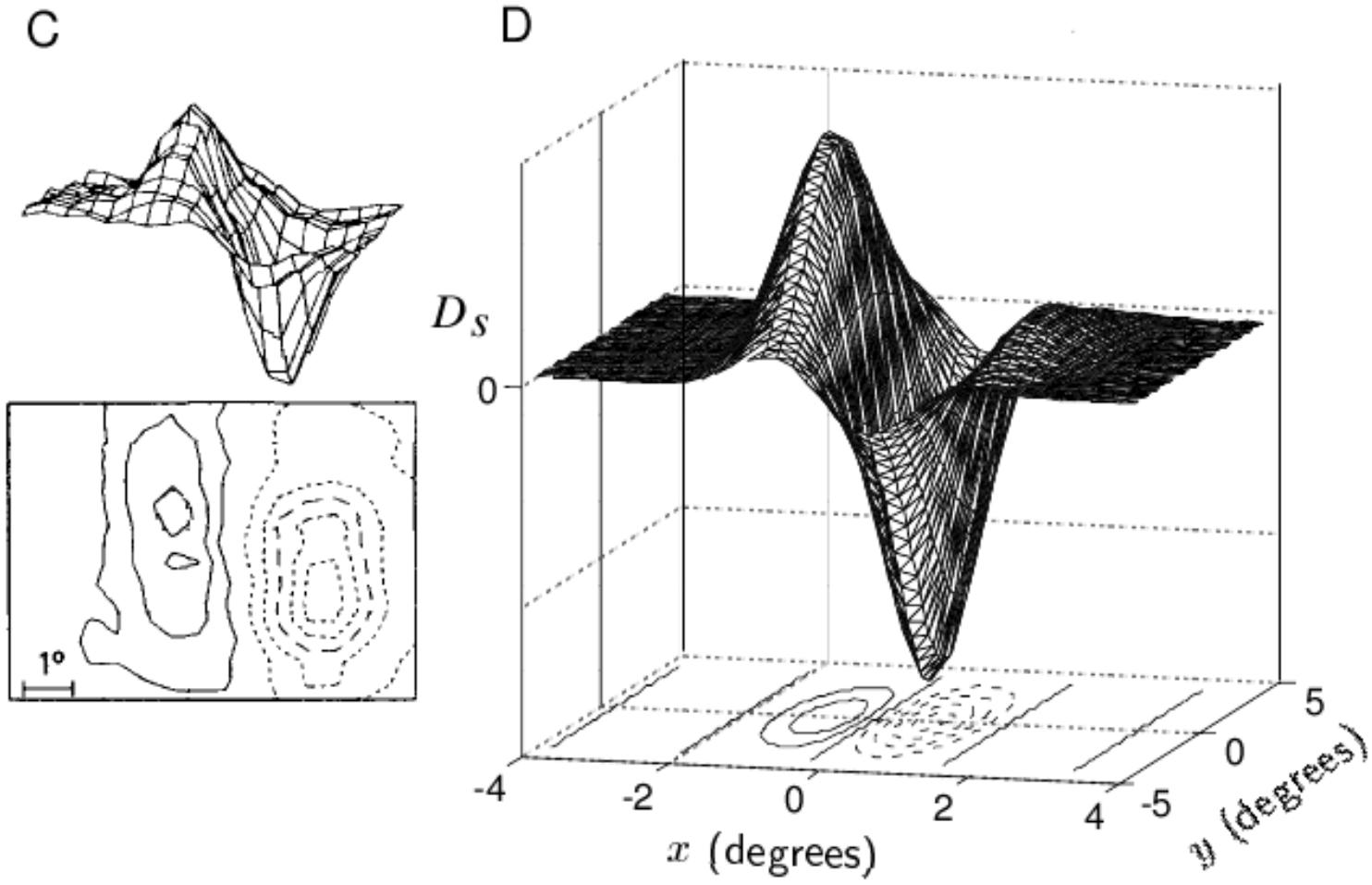


NEUROSCIENCE, Fourth Edition, Figure 1.13 (Part 2)

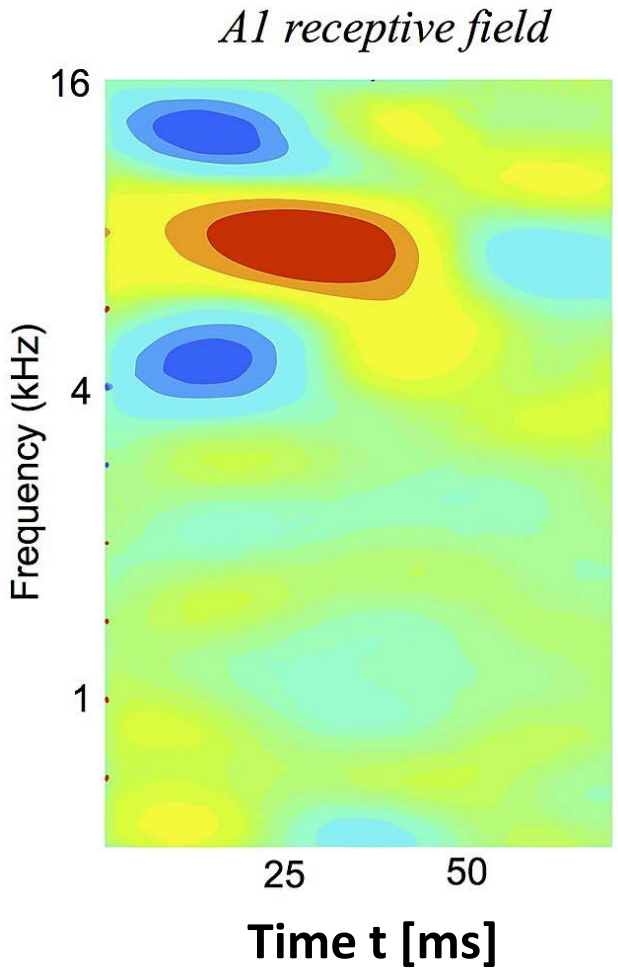
LGN receptive fields (visual system)



Simple cells receptive fields (visual cortex)



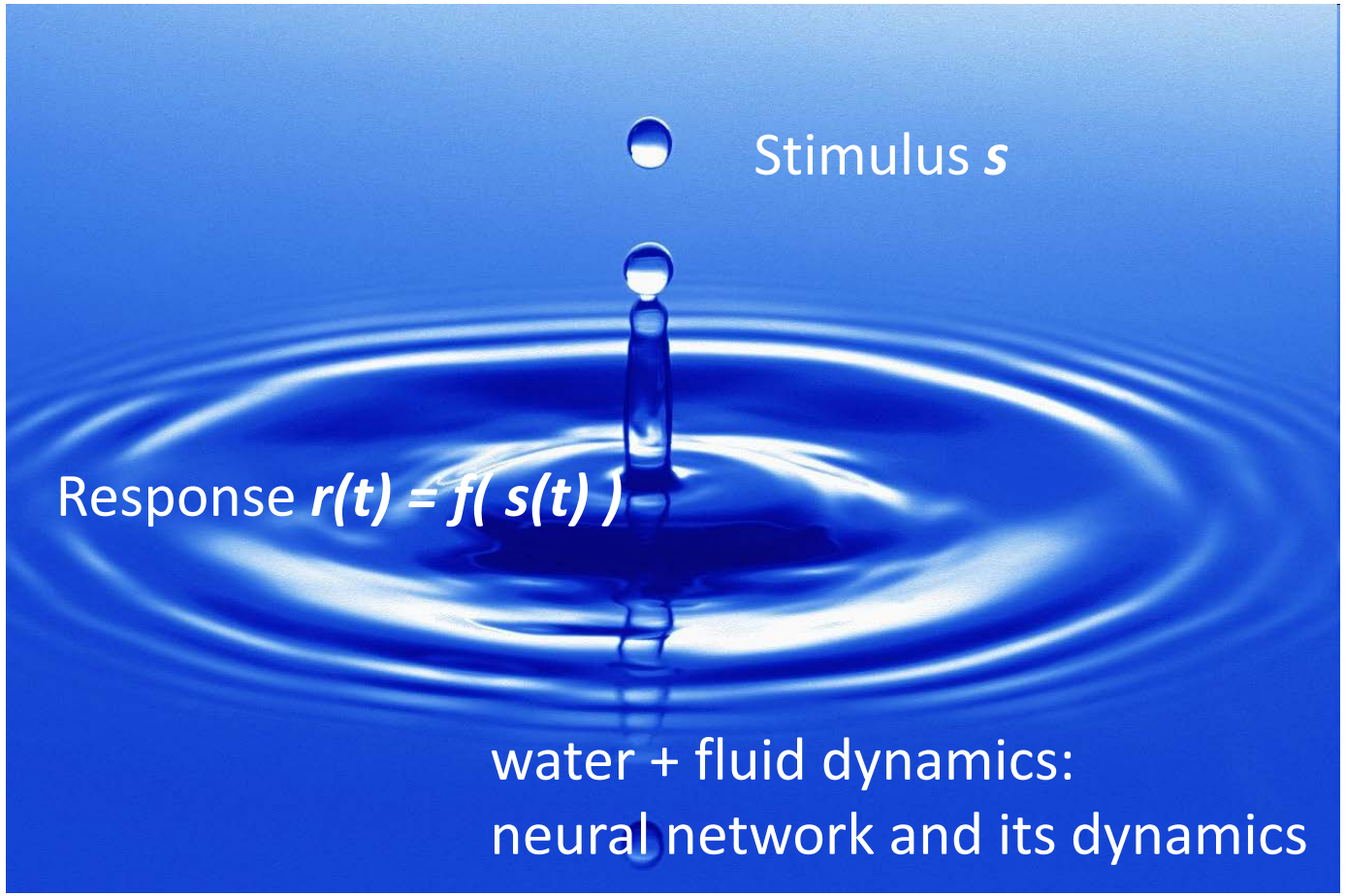
Auditory receptive fields (area A1)



...receptive field profiles have a temporal dynamics!

Central Idea

How to formalize for arbitrary stimuli?
- an analogy -

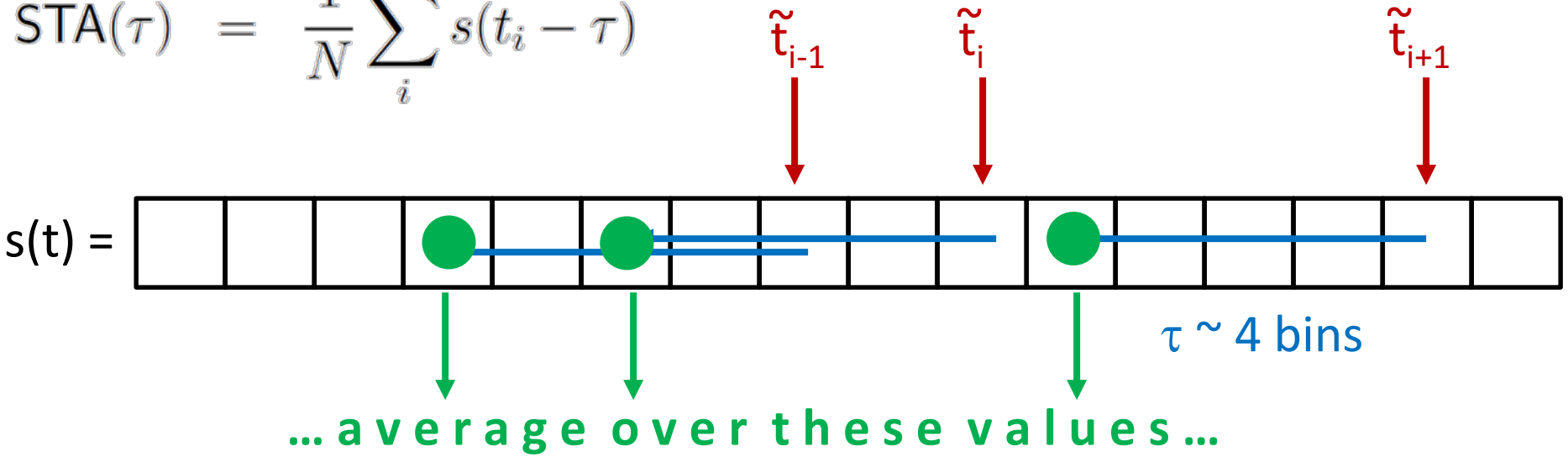


Spatio-temporal stimuli?
- superposition principle! -

Whiteboard

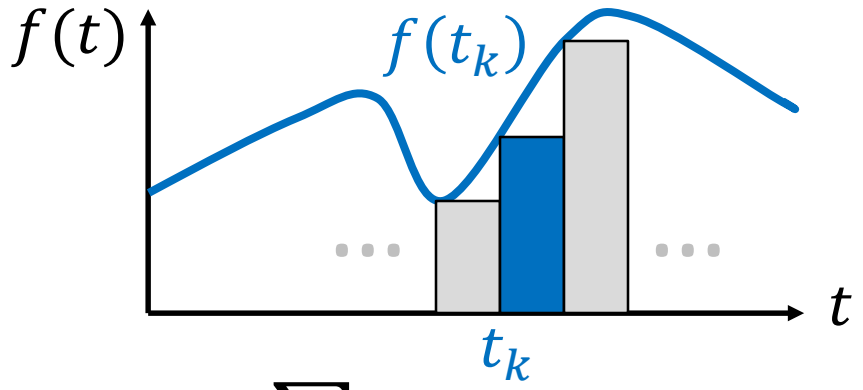
How to compute numerically?

a) $\mathrm{STA}(\tau) = \frac{1}{N}\sum_{i}^{N} s(\tilde{t}_i - \tau)$



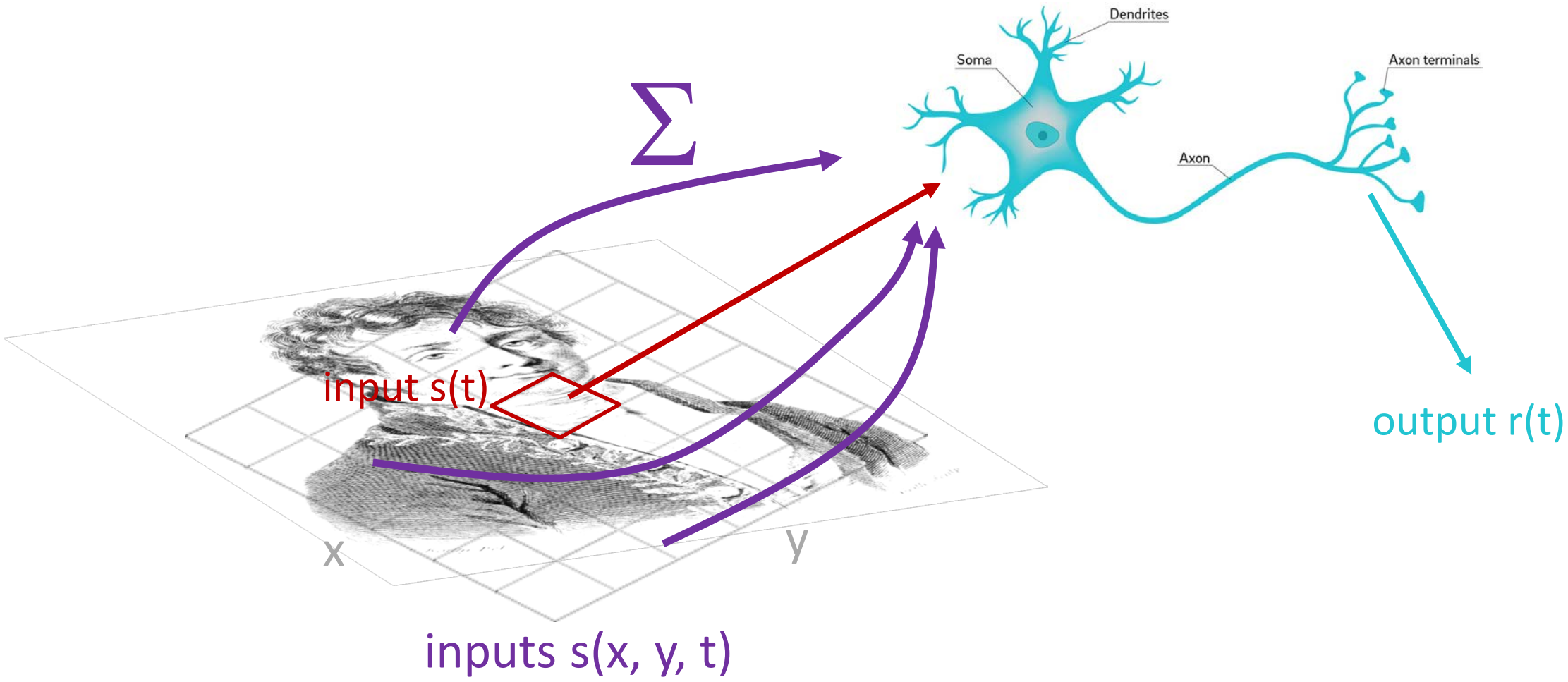
b) $\mathrm{RC}(\tau) = \frac{1}{\langle r \rangle T}\int_0^T s(t-\tau)r(t)dt$

$$RC(\tau) \approx \Delta t \sum_k s(t_k - \tau)r(t_k)$$



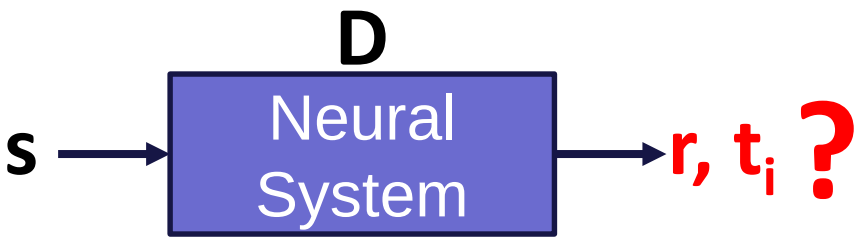
$$\int f(t)\,dt \approx \sum f(t_k)\,(t_{k+1} - t_k)$$

Extension 1-dimensional stimulus
→ n-dimensional stimulus



Summary

LNP, STA, RC

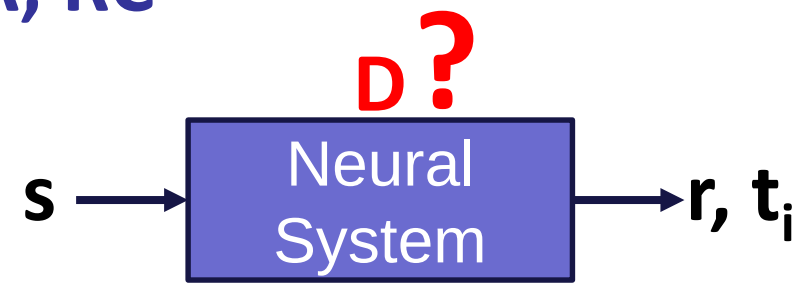


a) consider stimulus **s** composed of many single pulselike events

b) each event leads to a temporal response **D**

c) superimpose single responses to obtain the full linear response **L**

d) pass through gain function to obtain **r**, randomly sample spikes to obtain $\mathbf{t_i}$



a1) average stimulus **s** preceding spikes $\mathbf{t_i}$ by time τ

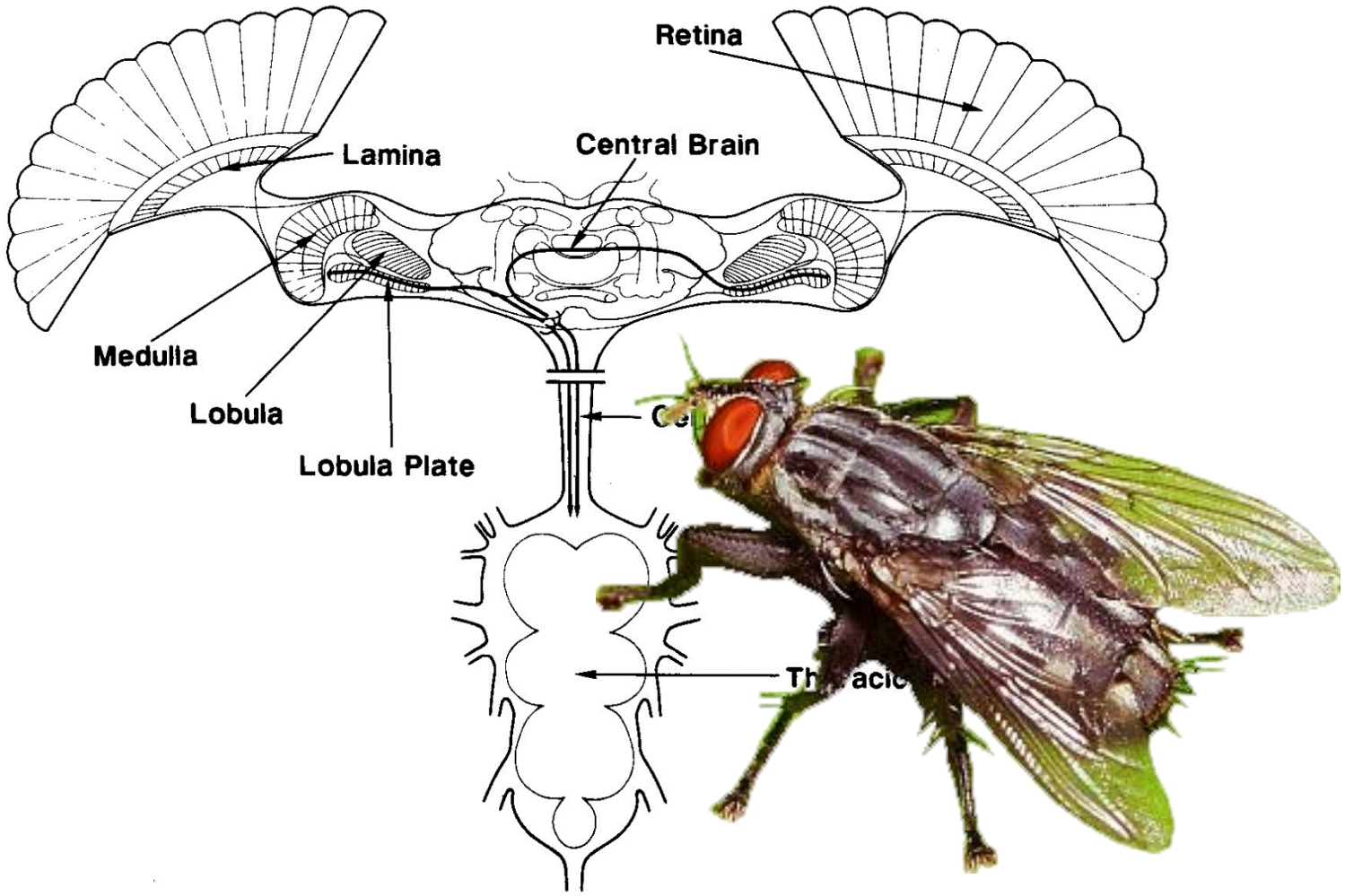
a2) average stimulus **s** preceding response **r** by time τ

b) thus obtain (linear) response kernel **D**

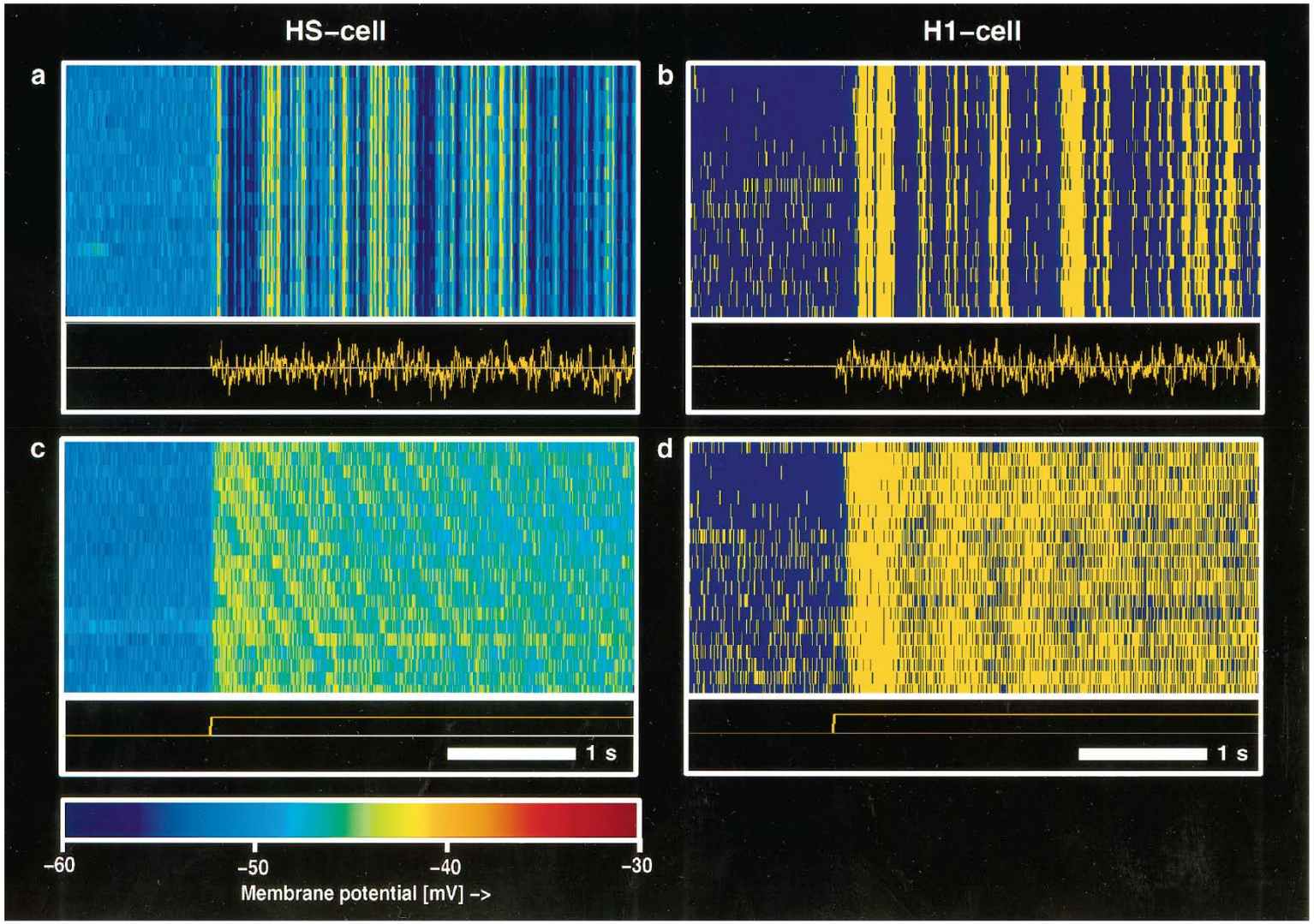
Caution: stimulus must have been uncorrelated noise! Otherwise, correct by inverse covariance matrix...

Example: 1-D

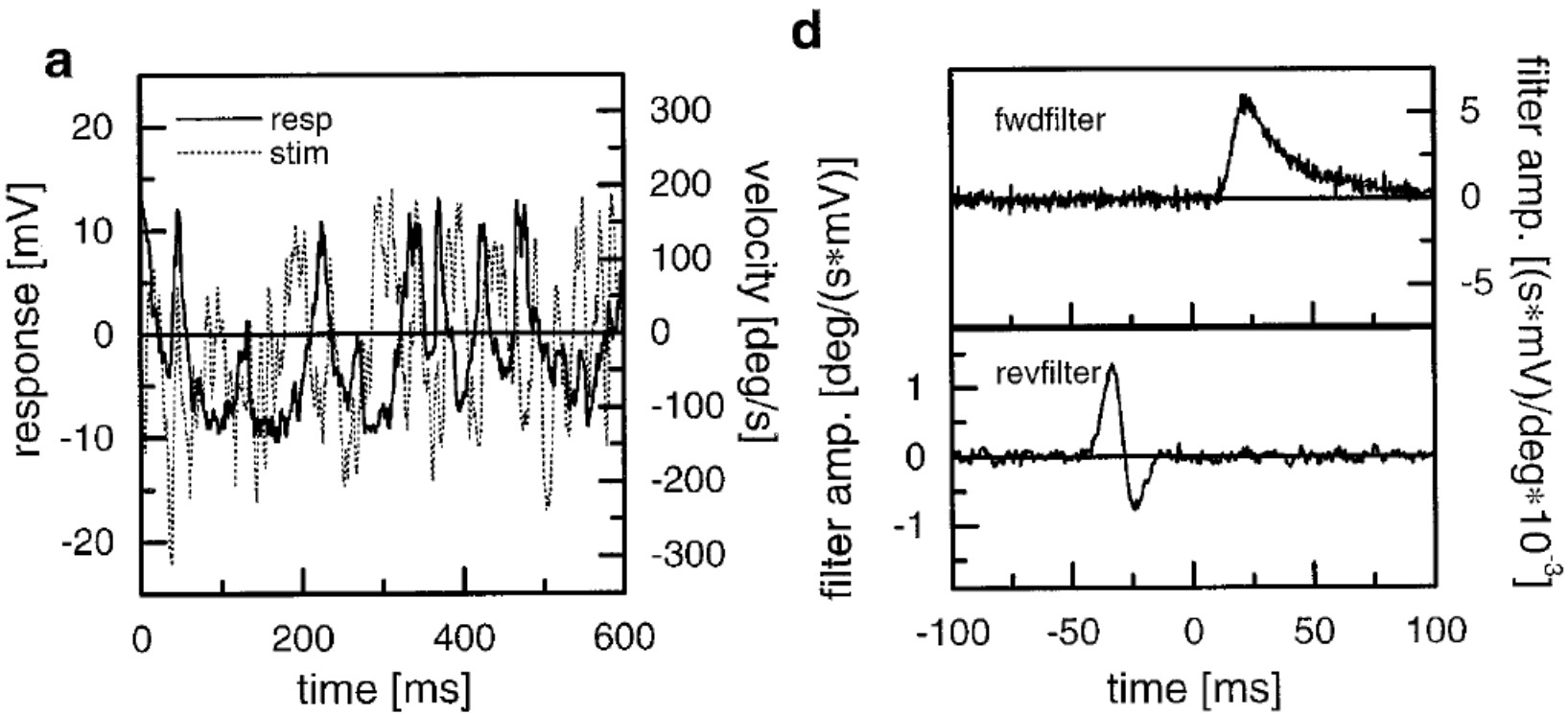
Let the brain Fly!!!



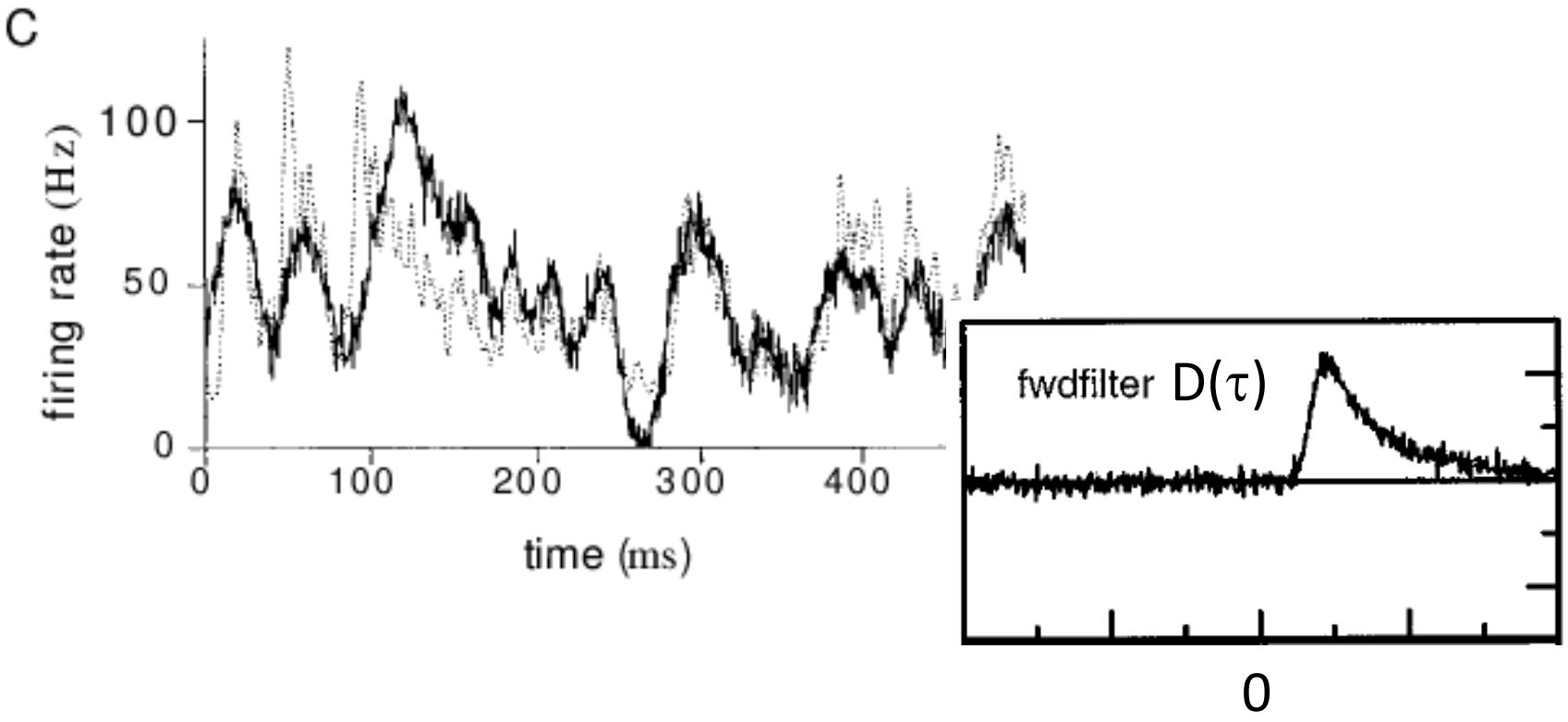
Let the brain Fly!!!



Let the brain Fly!!!

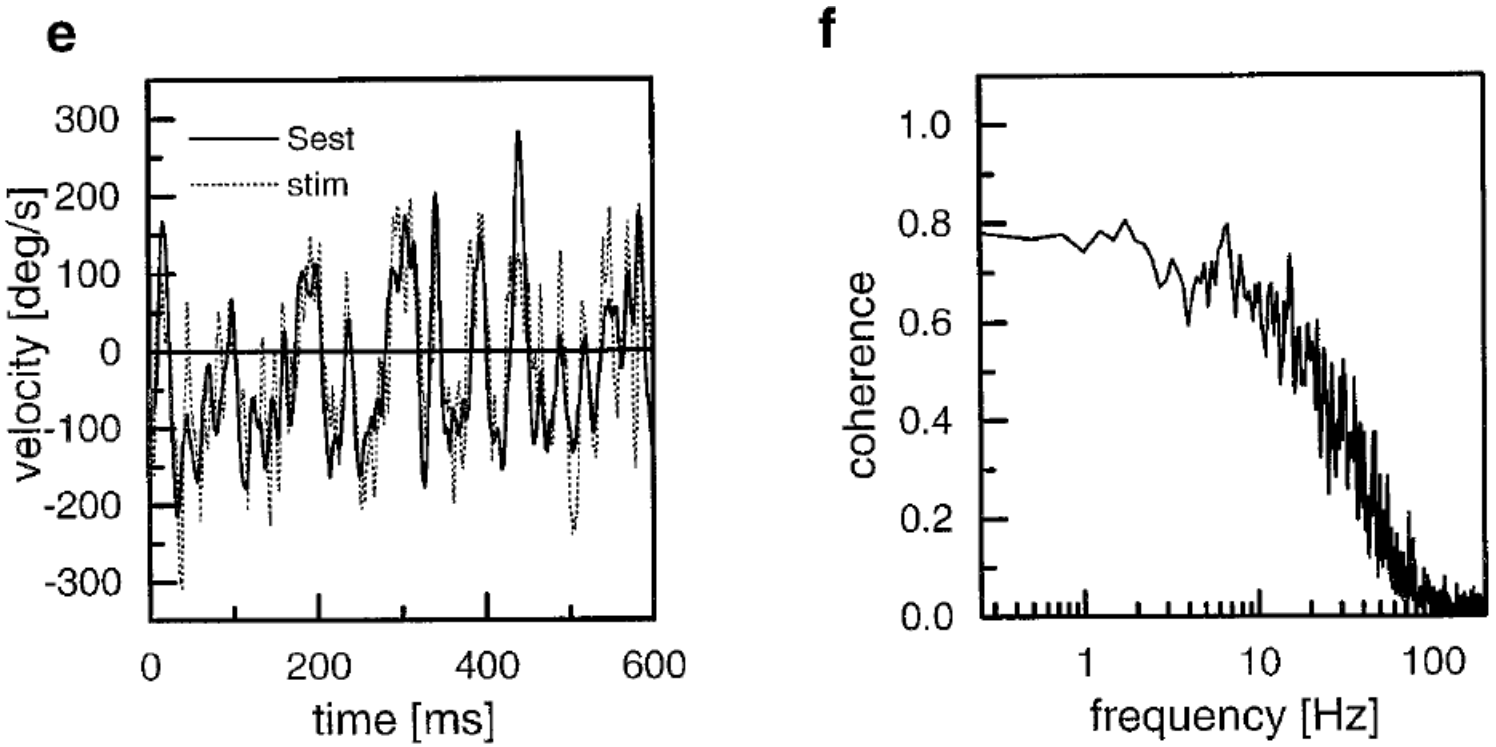


Let the brain Fly!!!



Predicting a response (solid line) from a stimulus...
Rieke et al. 1997]

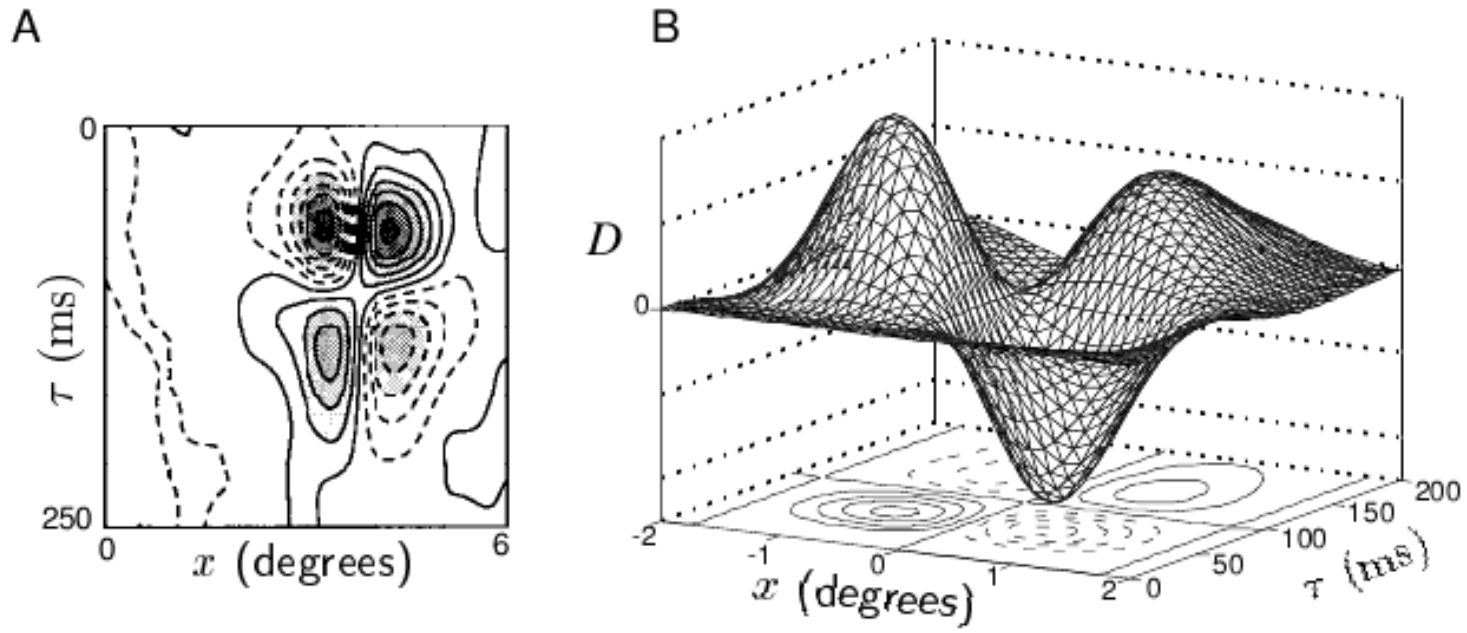
Let the brain Fly!!!



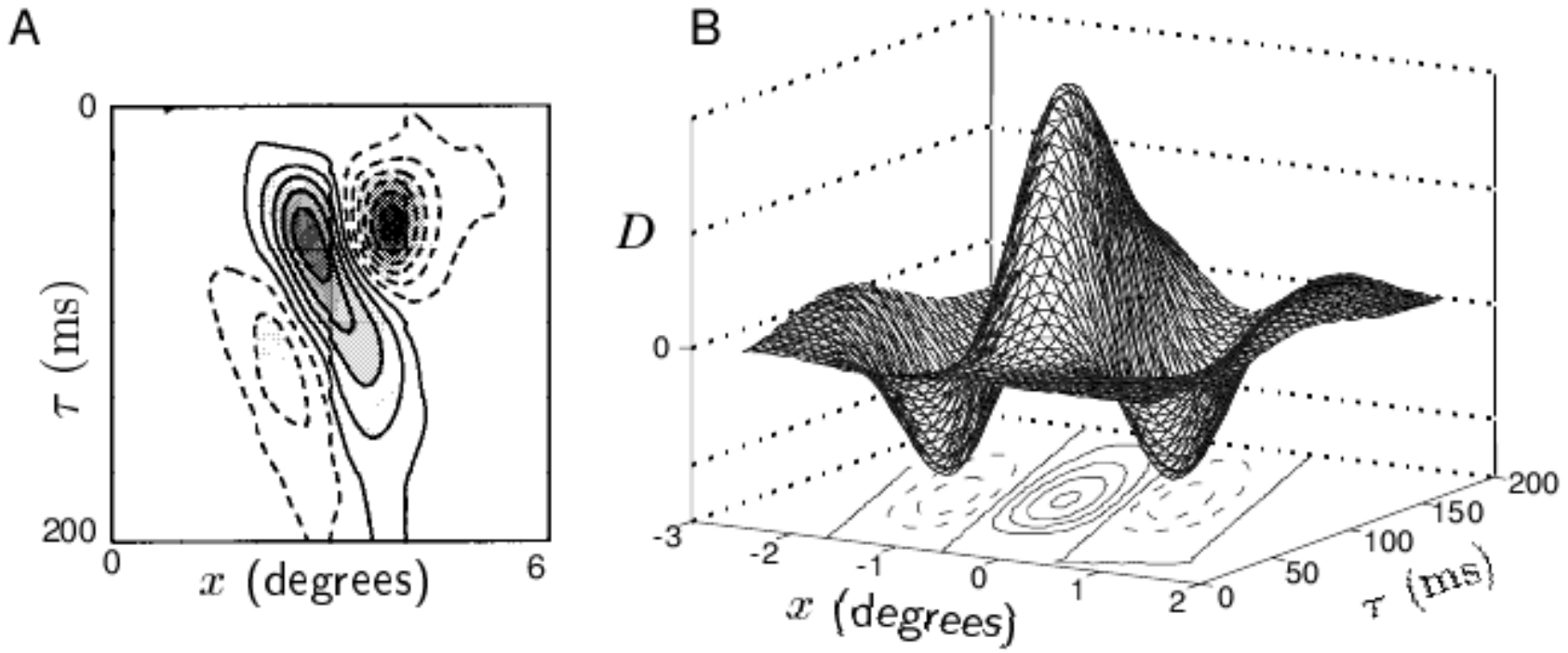
...and predicting a stimulus from a response. [Haag & Borst 1997]

Example: n-D

(Space-Time) Separable receptive fields

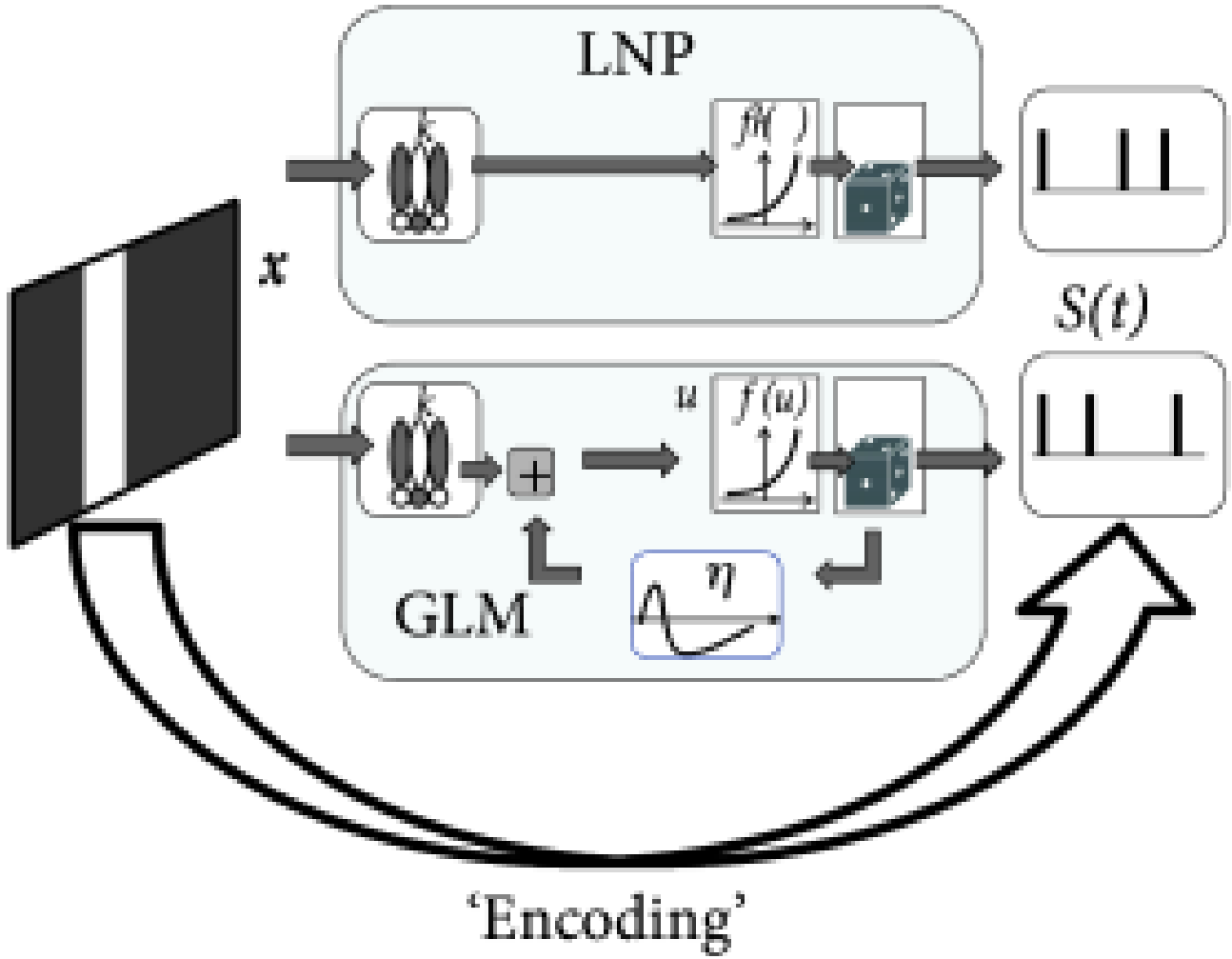


(Space-Time) Inseparable receptive fields

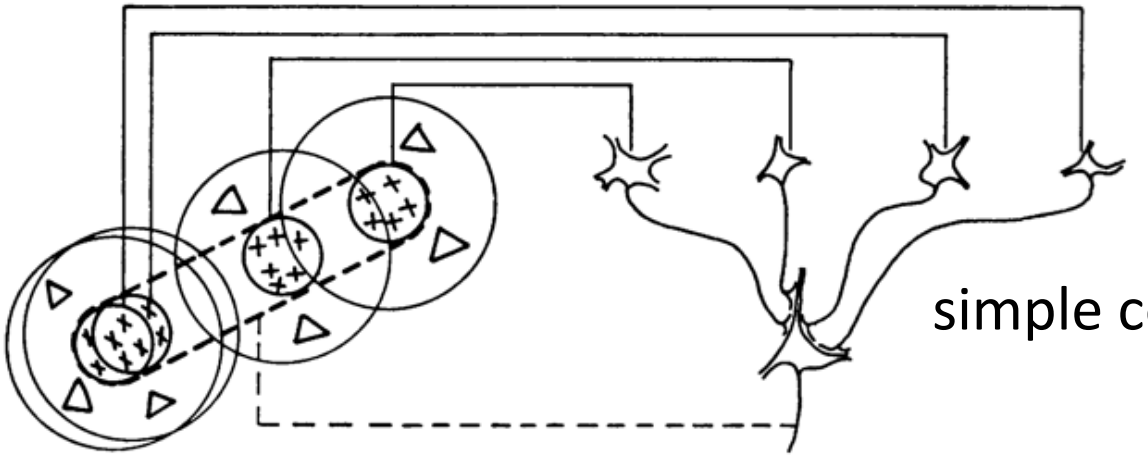


Generalized linear models (GLMs)

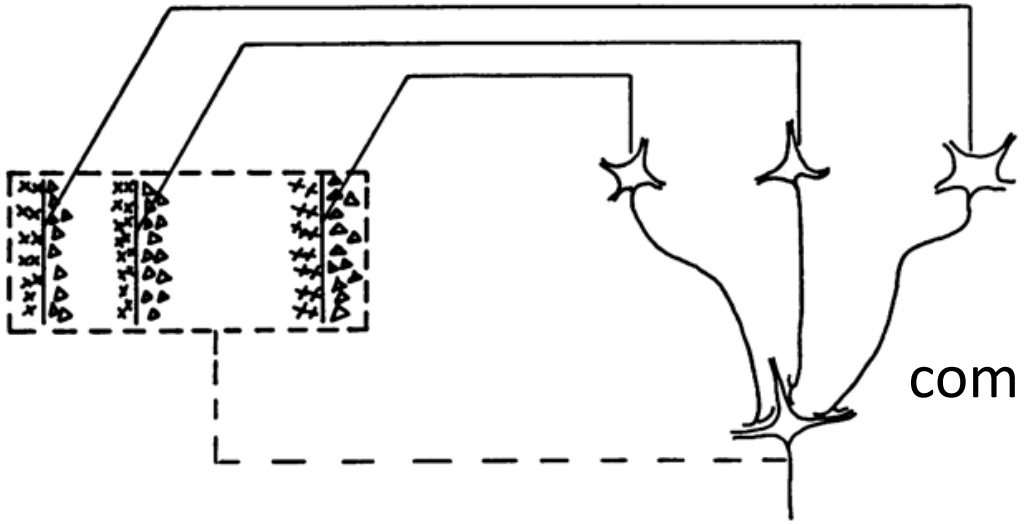
LNPs are simplified GLMs



The Hubel-Wiesel model is a GLM!



simple cells

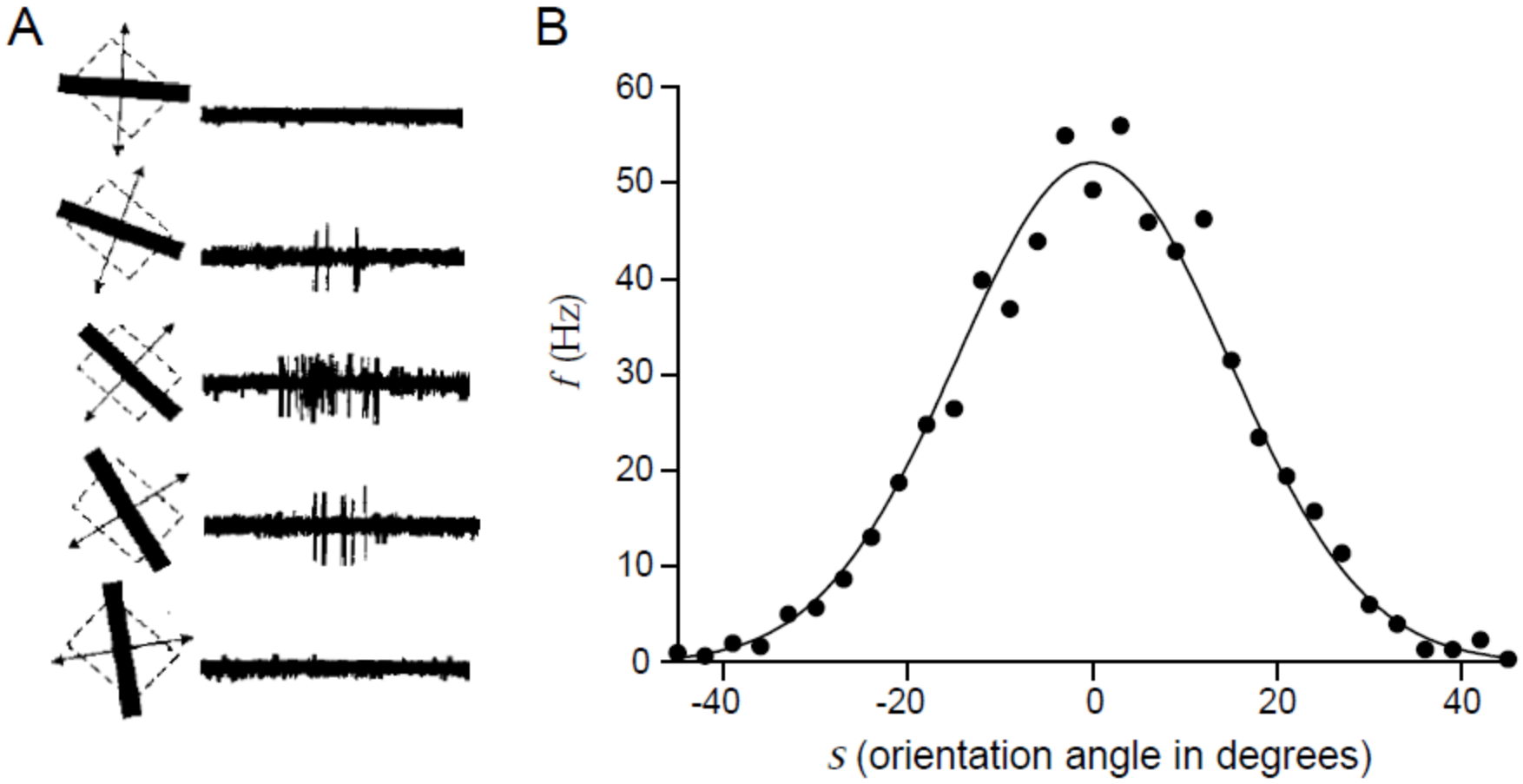


complex cells

Hubel & Wiesel, J. Physiol. 1962

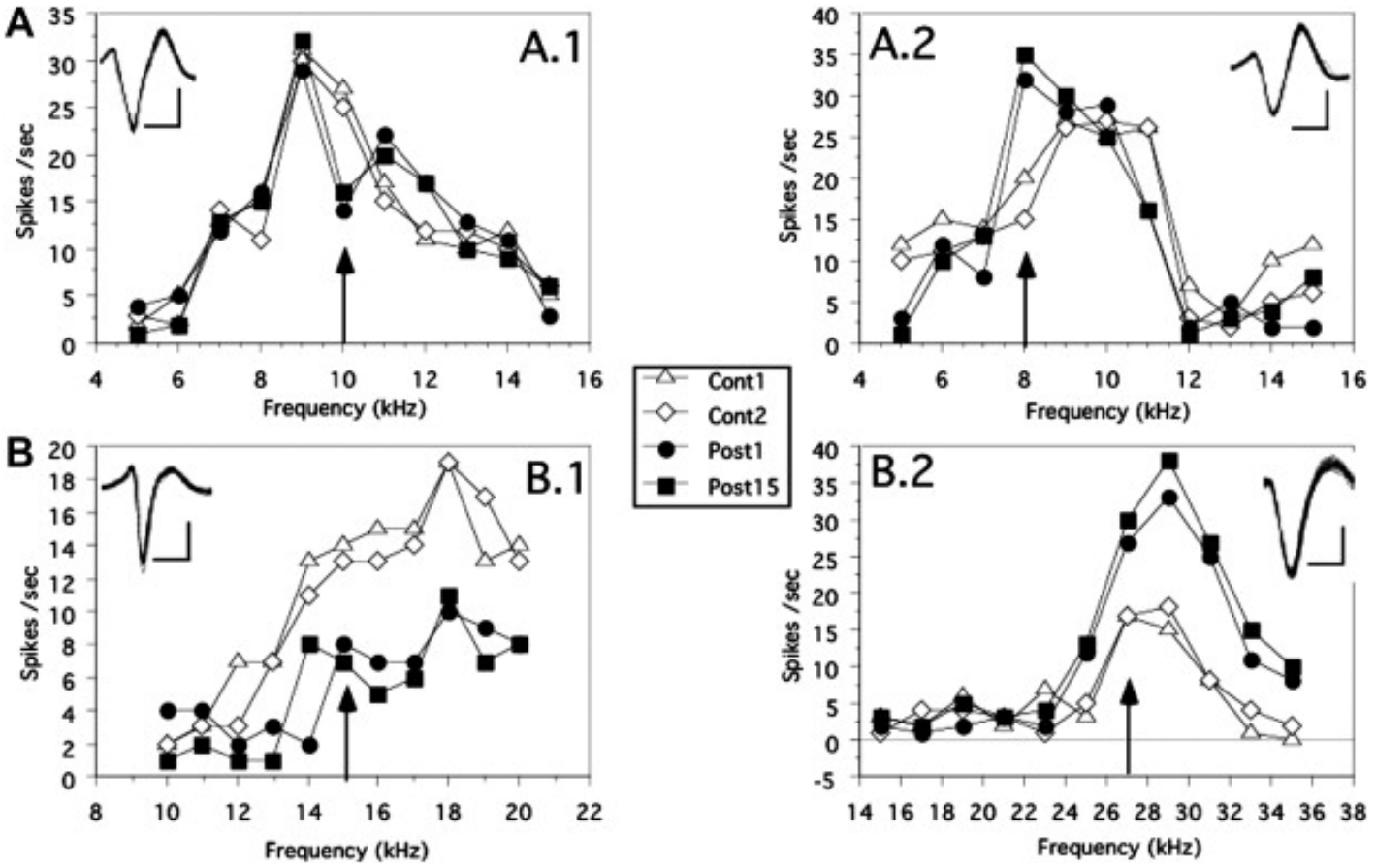
Tuning Curves

Tuning curves



...e.g., orientation tuning in (monkey) visual cortex

Tuning curves II



...e.g., frequency tuning in (rat) auditory cortex

Insights today...

1. The **LNP-model** - determine a neural response from a given stimulus and receptive field (response kernel)
2. The **STA or RC method** - determine the receptive field (response kernel) from a given stimulus and neural response
3. Other aspects: **Bussgang's theorem, methodological constraints, GLMs**