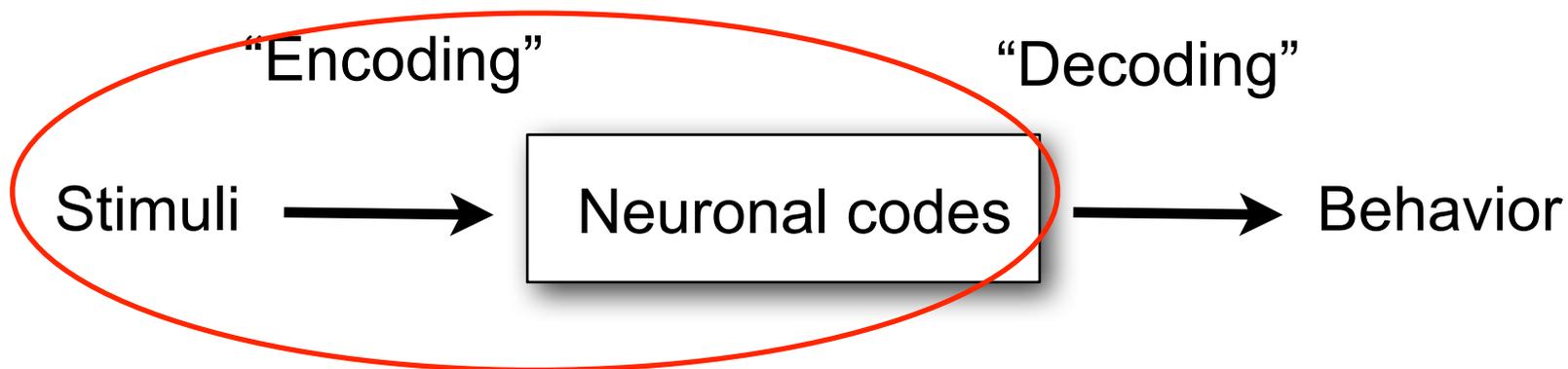# Lecture overview

- What hypothesis to test in the fly?

- Quantitative data collection

- Visual physiology conventions ("Methods")

Lecture overview

- **What hypothesis to test in the fly?**
- Quantitative data collection
- Visual physiology conventions ("Methods")

"Encoding"   "Decoding"

Stimuli ⟶ Neuronal codes ⟶ Behavior

General situation in vision encoding studies:

Independent variable: pattern of photons

Dependent variable: pattern of spikes from one or more neurons

A specific case (e.g. for H1 in the fly):

Independent variable: direction of a moving grating

Dependent variable: spike rate during each the presentation of each grating

spikes per unit time (spikes/sec)

Overall goal of the fly labs: the basics of carrying out a complete, quantitative neurophysiology experiment.

- Design visual stimuli to test a hypothesis

  MATLAB proj 2
  Design lab

- Setup a prep to record from relevant neurons

  FLY wet lab 1

  A hypothesis or description about the relationship between visual stimuli and a neuronal response

-

  FLY wet lab 2

- Collect digital data during that presentation

  FLY wet lab 2

- Isolate individual spikes in that data

  MATLAB proj 1

- Analyze the relationship between spike responses and visual stimuli

  MATLAB proj 3
  Data analysis lab

- Document your findings

  Lab Report 2

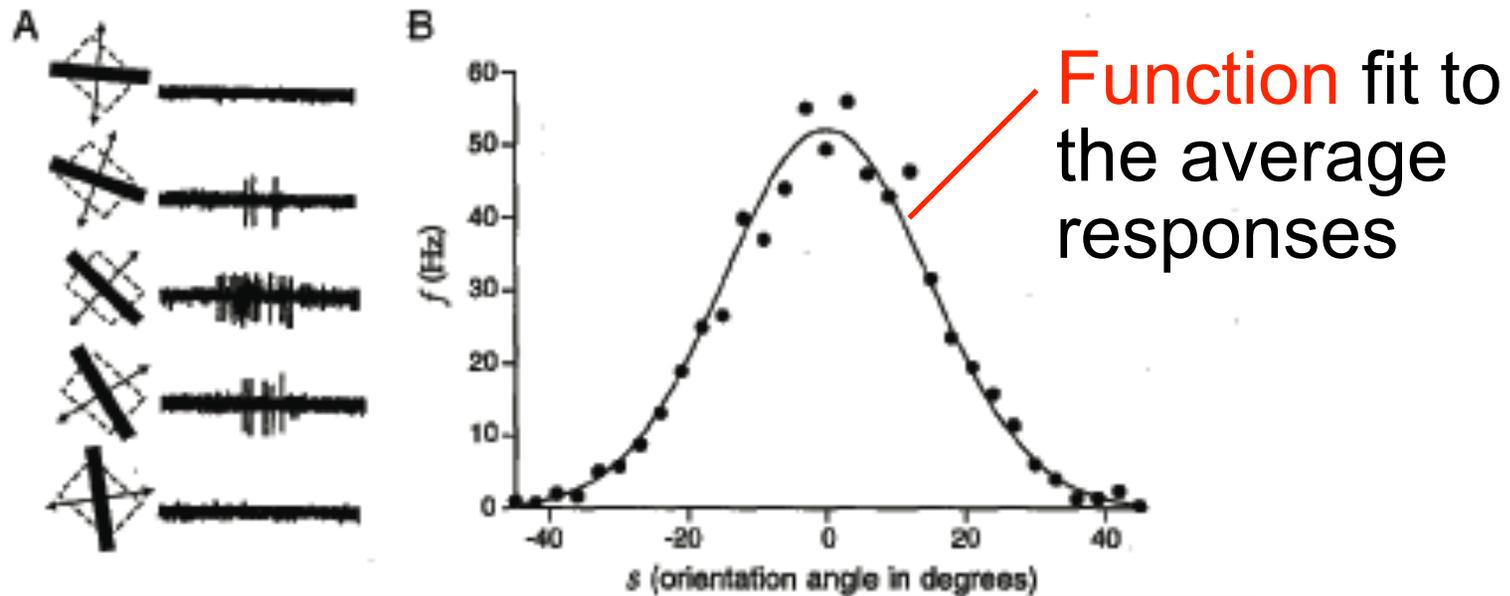# Example of quantitative neurophysiology: orientation tuning a neuron in primary visual cortex (area V1) of the monkey.
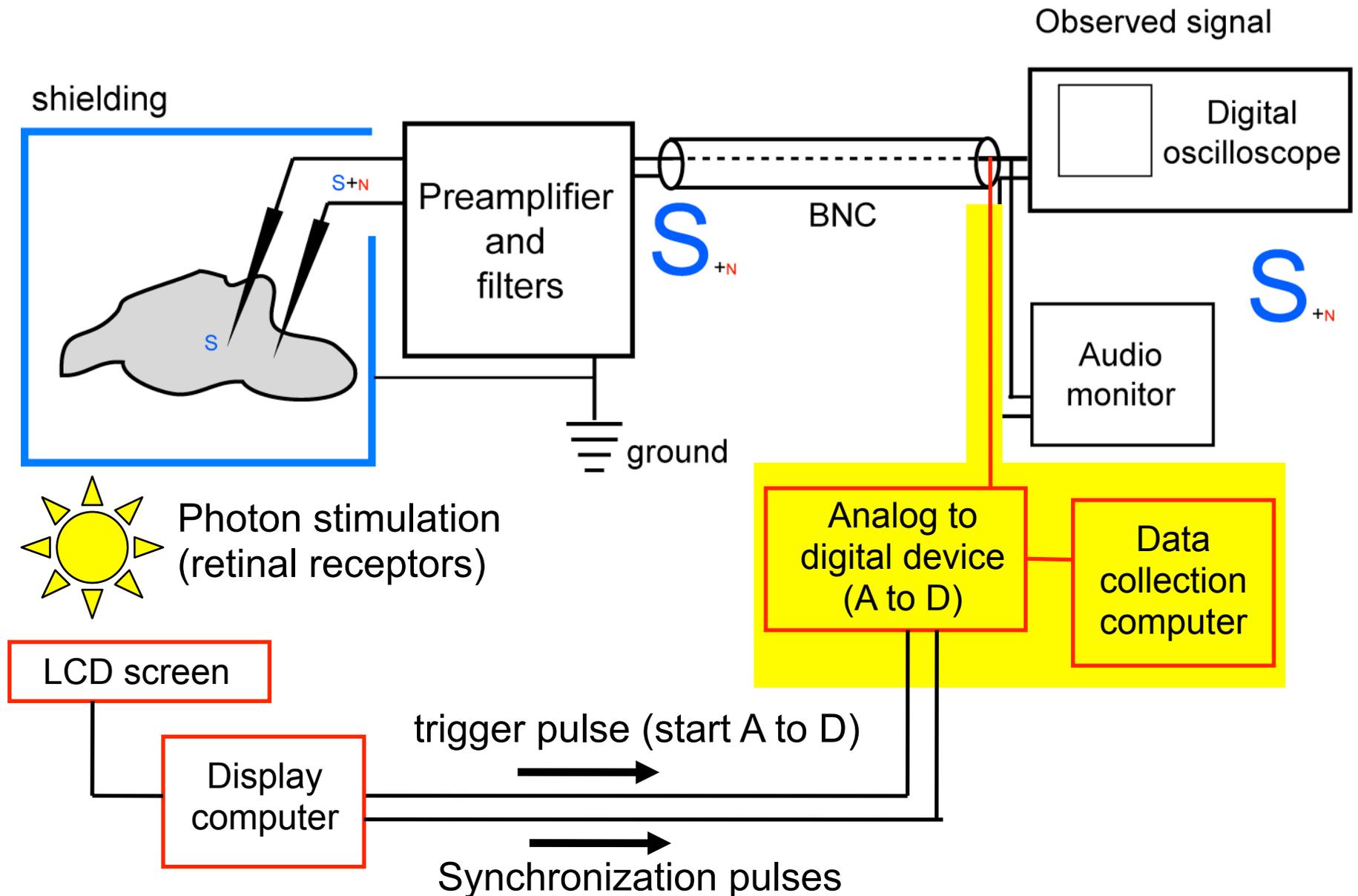

Function fit to the average responses

One of our overarching goals is to teac [ ] ey. you how these kind of plots are produce[ ]

You will do all the steps yourself!

Figu[ ] A ba[ ] es. The [ ] are and [ ] is indic[ ] ght bar f[ ] as a function of the orientation angle of the light bar stimulus. The curve is a fit using the function 1.14 with parameters $r_{max} = 52.14$ Hz, $s_{max} = 0°$, and $\sigma_f = 14.73°$. (A adapted from Wandell, 1995, based on an original figure from Hubel and Wiesel, 1968; B data points from Henry et al., 1974).)

From Dayan, Peter, and L. F. Abbott. *Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems*. MIT Press, 2001. © Massachusetts Institute of Technology. Used with permission.

Lecture overview

- What hypothesis to test in the fly?
- Quantitative data collection
- Visual physiology conventions ("Methods")

Basic electrophysiological setup

Observed signal

shielding

S+N

Preamplifier and filters

S_{+N}

BNC

ground

Digital oscilloscope

S_{+N}

Audio monitor

Photon stimulation (retinal receptors)

Analog to digital device (A to D)

Data collection computer

LCD screen

trigger pulse (start A to D)

Display computer

Synchronization pulses

We must have some way of saving the voltage signal so that we can find the spikes (action potentials) later

Analog

Digital

1 ms (1/1000 sec)
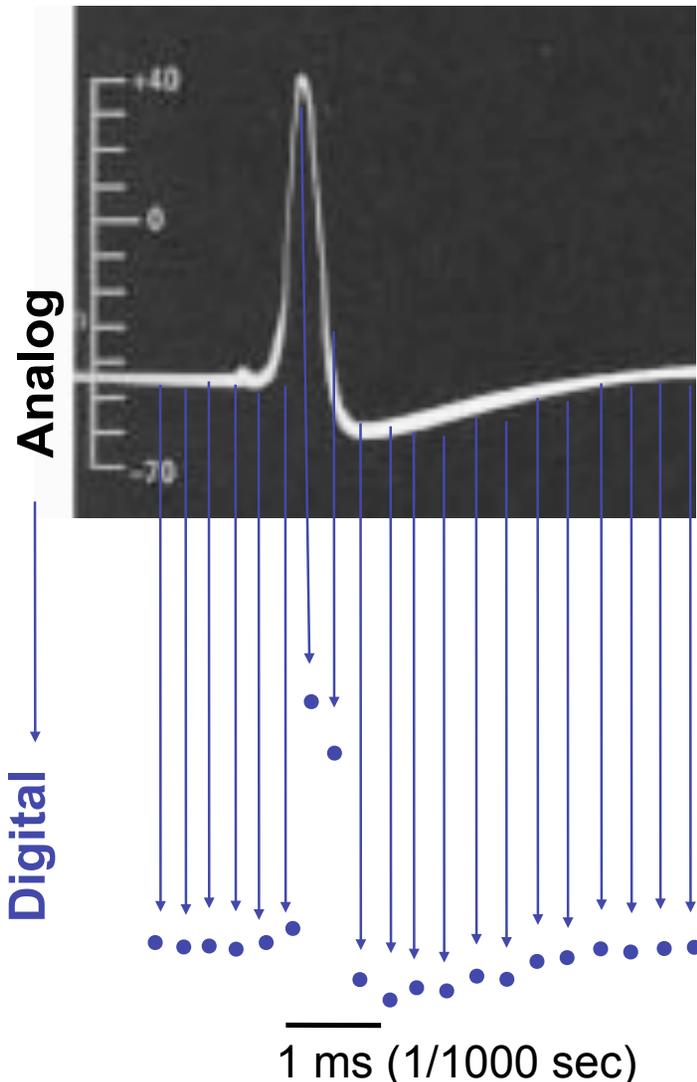
A single action potential

Analog to digital device (A to D)

Number of samples taken every second:

    1000   (1 kHz sampling)

    2000   (2 kHz sampling)

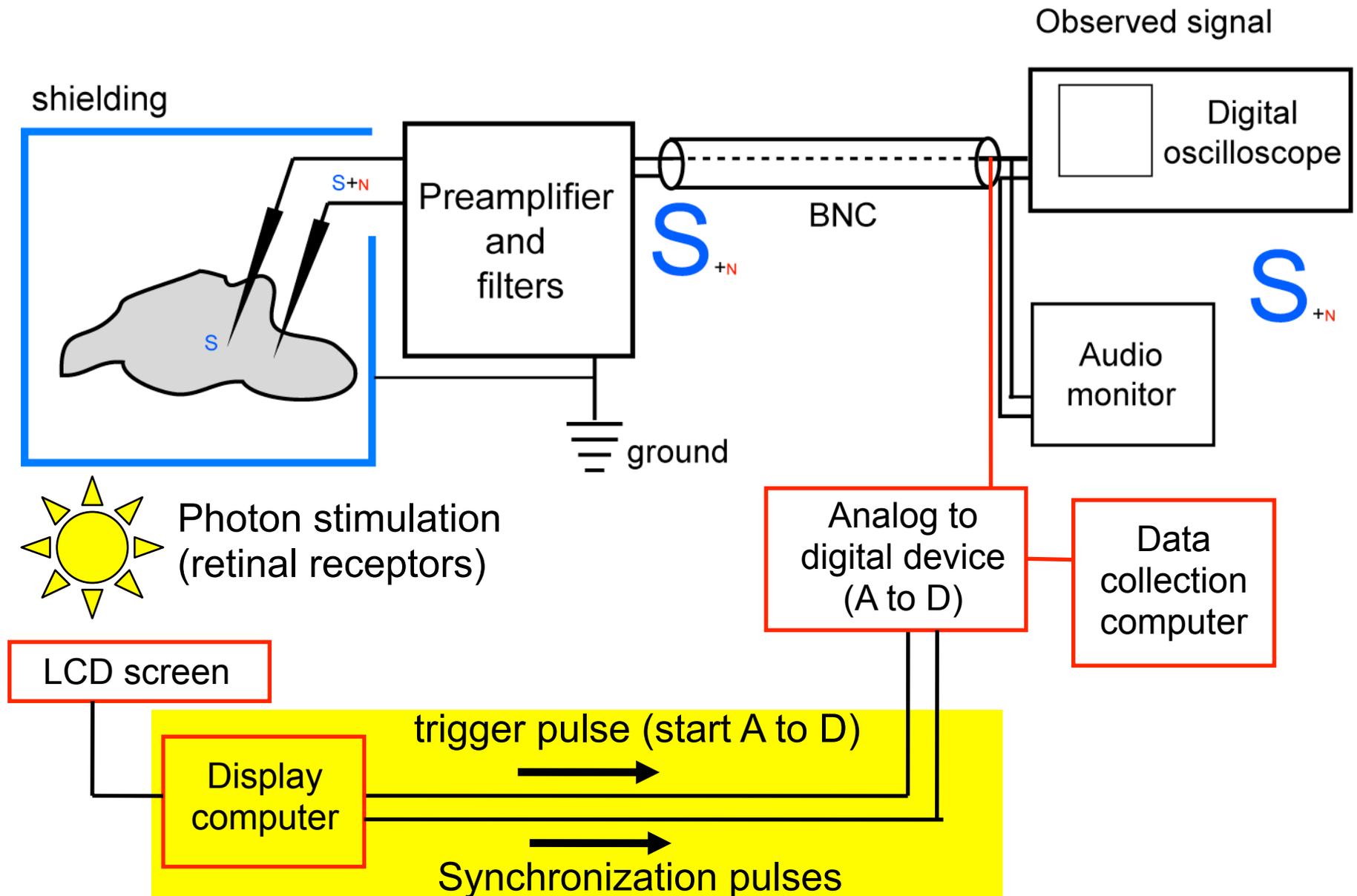   4000   (4 kHz sampling)

What sampling rate is optimal?

Are there downsides to sampling faster?

*Sample at 2x the highest frequency in the signal to get a perfect reproduction of the signal (= "Nyquist sampling rate").
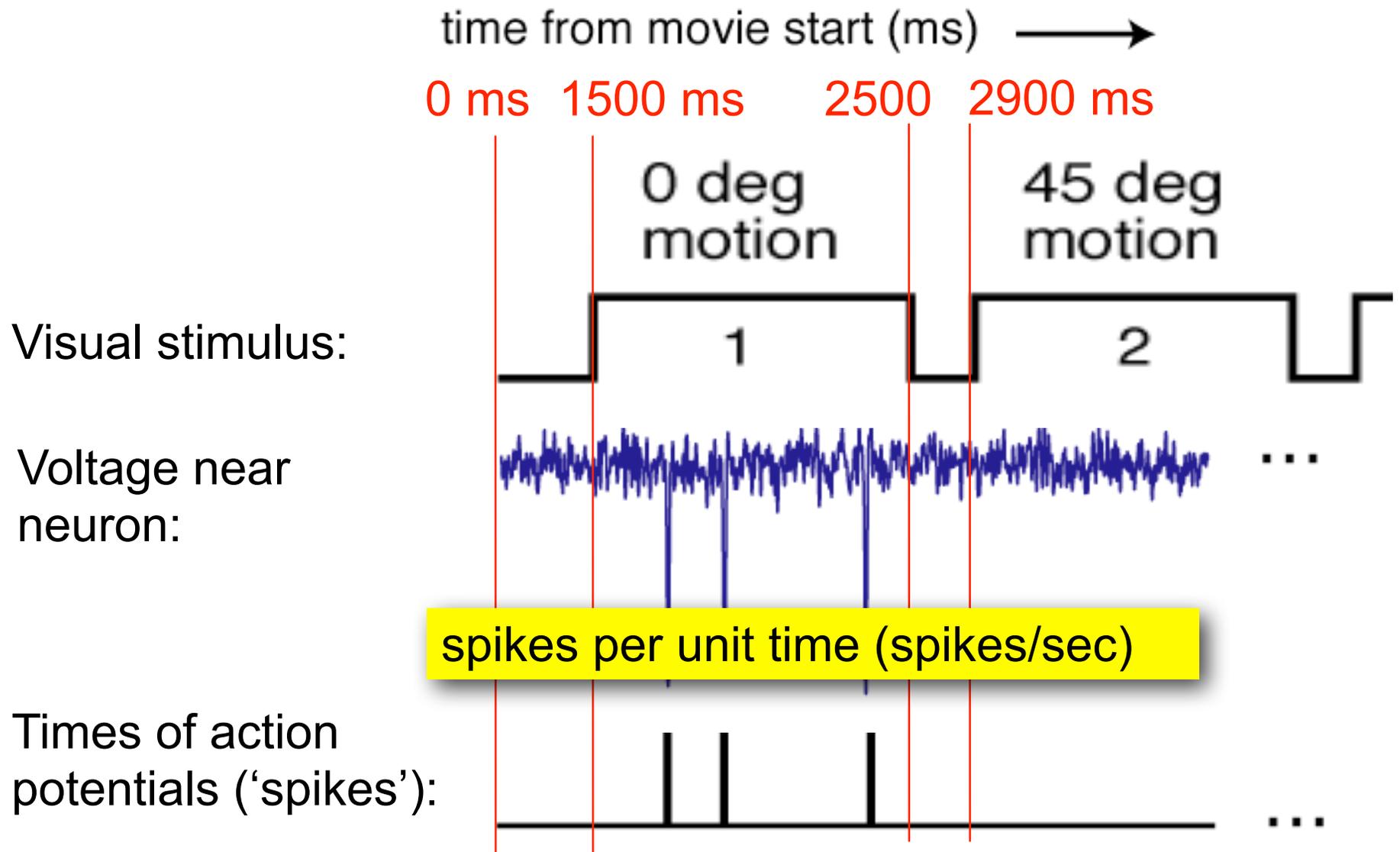
Basic electrophysiological setup

Observed signal

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Digital oscilloscope

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S_{+N}

Photon stimulation (retinal receptors)

Analog to digital device (A to D)

Data collection computer

LCD screen

trigger pulse (start A to D)

Display computer

Synchronization pulses

We must have some way of aligning (synchronizing) the visual stimulus with the recorded voltage

time from movie start (ms) ⟶

0 ms   1500 ms   2500   2900 ms

0 deg motion   45 deg motion

Visual stimulus: 1   2

Voltage near neuron: ...

spikes per unit time (spikes/sec)

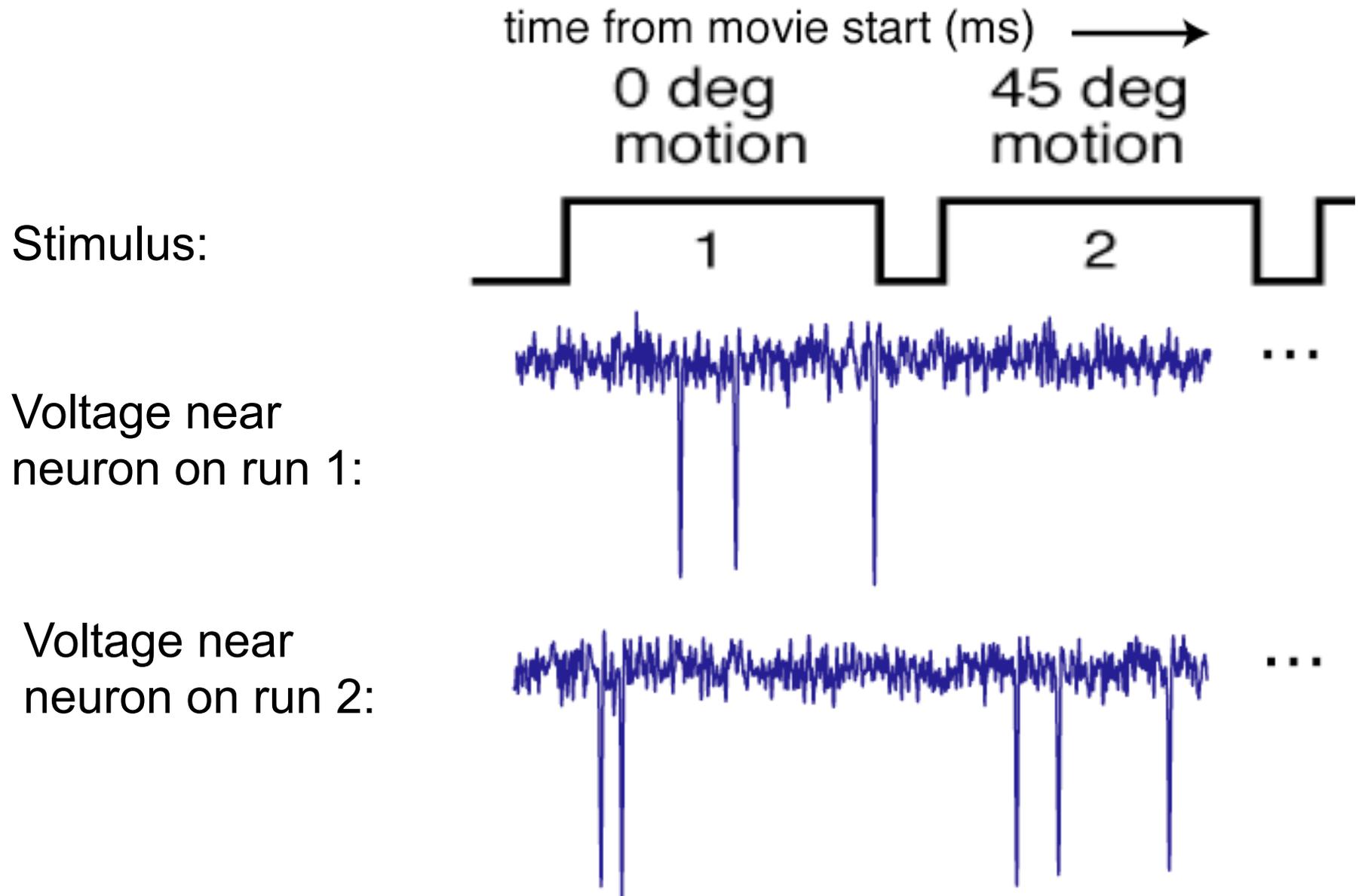Times of action potentials ('spikes'):   ...

First steps to quantitative physiology (science):

- Ability to accurately repeat conditions.

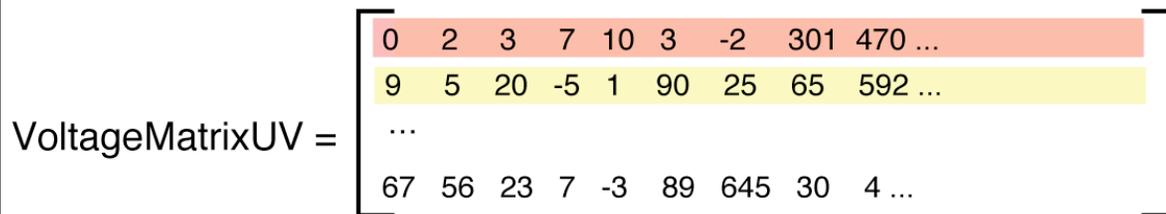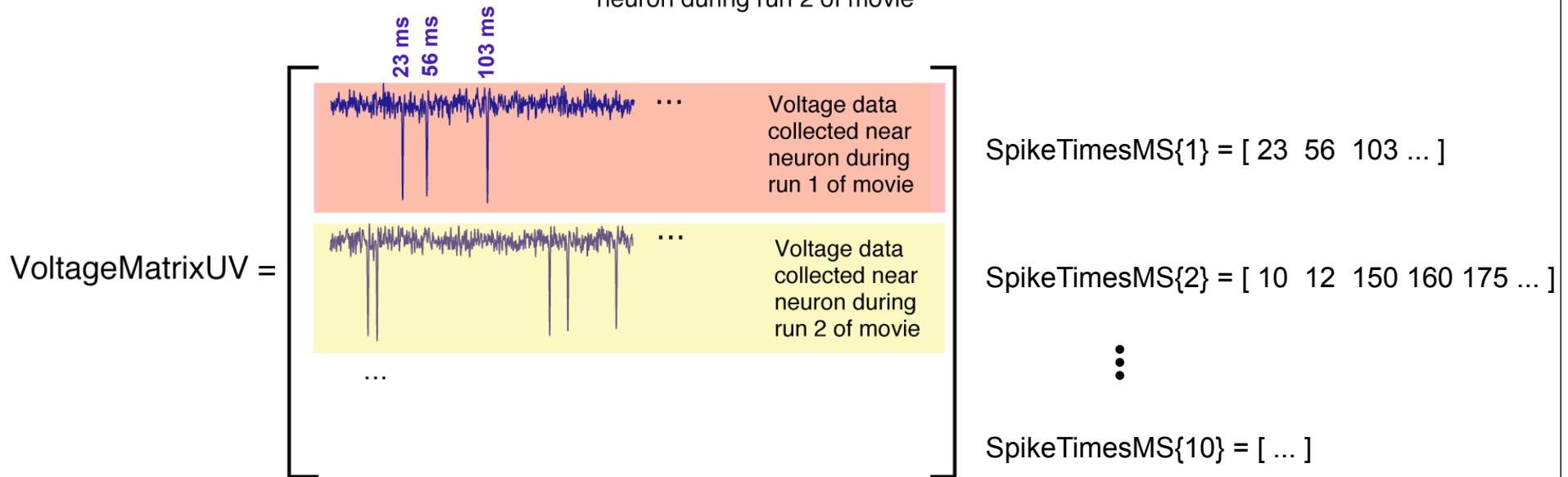- Control of variables -- only change one thing at a time!

time from movie start (ms) →

| 0 deg motion | 45 deg motion |

Stimulus run 1:   1   2

| 0 deg motion | 45 deg motion |

Stimulus run 2:   1   2

Example voltage traces

time from movie start (ms) ⟶

0 deg
motion

45 deg
motion

Stimulus:

1

2

Voltage near
neuron on run 1:
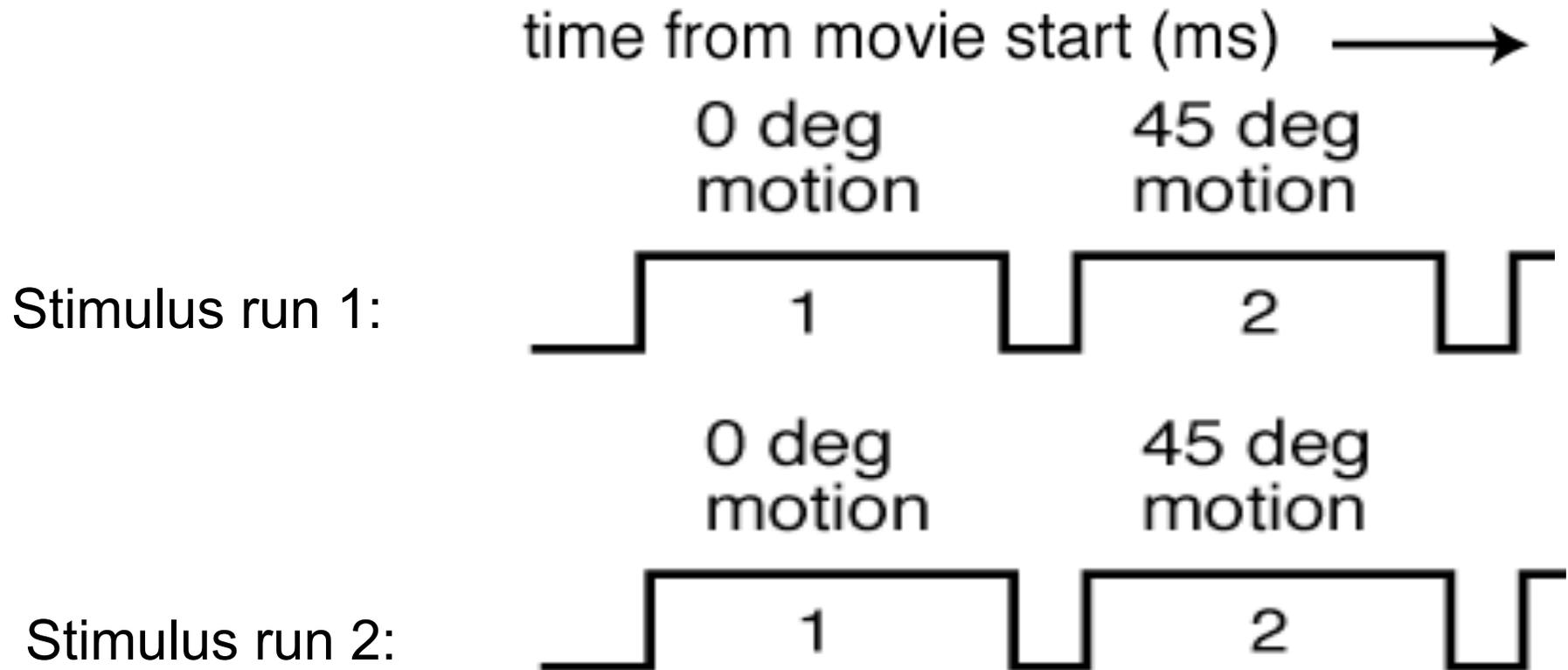
Voltage near
neuron on run 2:

VoltageMatrixUV(1,:) = row 1 of matrix = Voltage data collected near neuron during run 1 of movie

VoltageMatrixUV(2,:) = row 2 of matrix = Voltage data collected near neuron during run 2 of movie
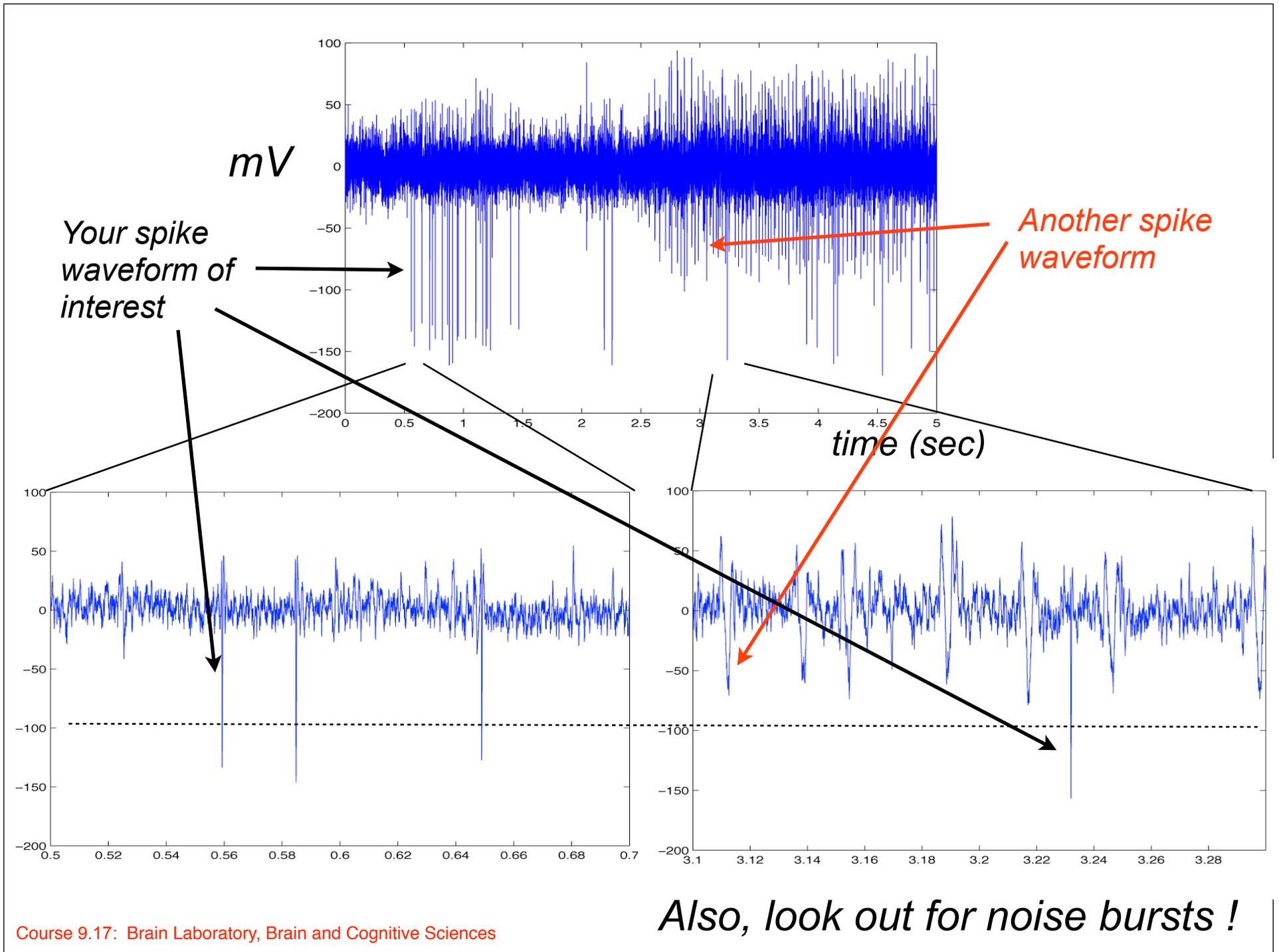
VoltageMatrixUV =

23 ms 56 ms 103 ms

Voltage data collected near neuron during run 1 of movie

Voltage data collected near neuron during run 2 of movie

...

SpikeTimesMS{1} = [23 56 103 ...]

SpikeTimesMS{2} = [10 12 150 160 175 ...]

⋮

SpikeTimesMS{10} = [...]

VoltageMatrixUV =

0	2	3	7	10	3	-2	301	470 ...
9	5	20	-5	1	90	25	65	592 ...
...								
67	56	23	7	-3	89	645	30	4 ...

TimesMS = [0 0.05 0.1 0.015 0.02 0.025 ...   ... 10999.95 11000]

time from movie start (ms) ⟶

Spike sorting:

You learned how to so spike detection in Matlab Tutorial 1. However, that was relatively clean data. Your data file may be much messier and may contain many artifacts that you should try to deal with. For example, if the fly moves, this creates a lot of noise in the voltage trace, and a simple spike detector might count this noise as spikes. Thus, you should NOT blindly run a spike detector, but should examine your data closely and make sure the spike detector is doing something reasonable.

mV

Your spike waveform of interest

Another spike waveform

time (sec)

Also, look out for noise bursts !

H1 cell   Post-stimulus time histogram (PSTH)

Figure 4 removed due to copyright restrictions. Eckert, Hendrik. "Functional Properties of the HI-Neurone in the Third Optic Ganglion of the Blowfly, Phaenicia." *Journal of Comparative Physiology A* 135, no. 1 (1980): 29-39. 10.1007/BF00660179.
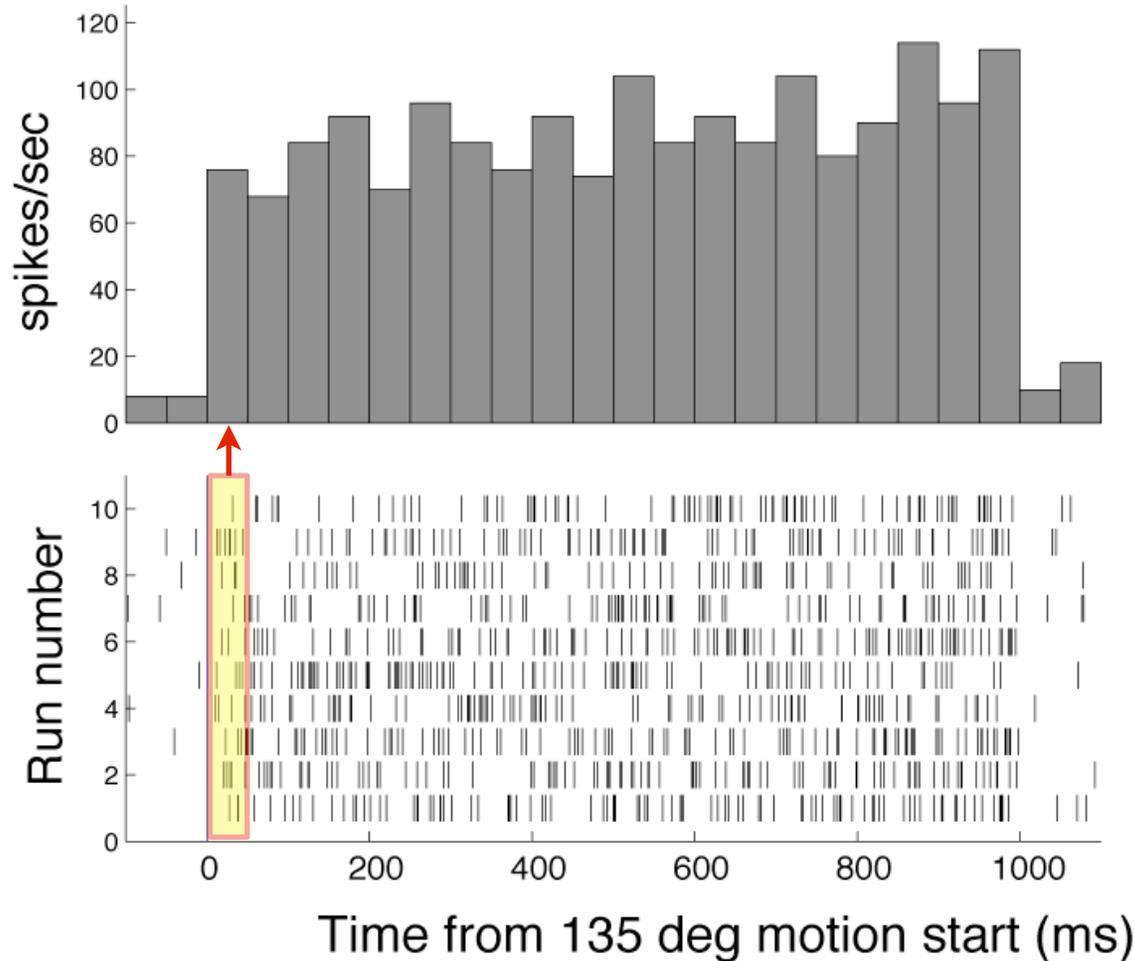
H. Eckert: Properties of the H1-Neurone in the Fly Optic Lobe

Neuronal spiking is variable:
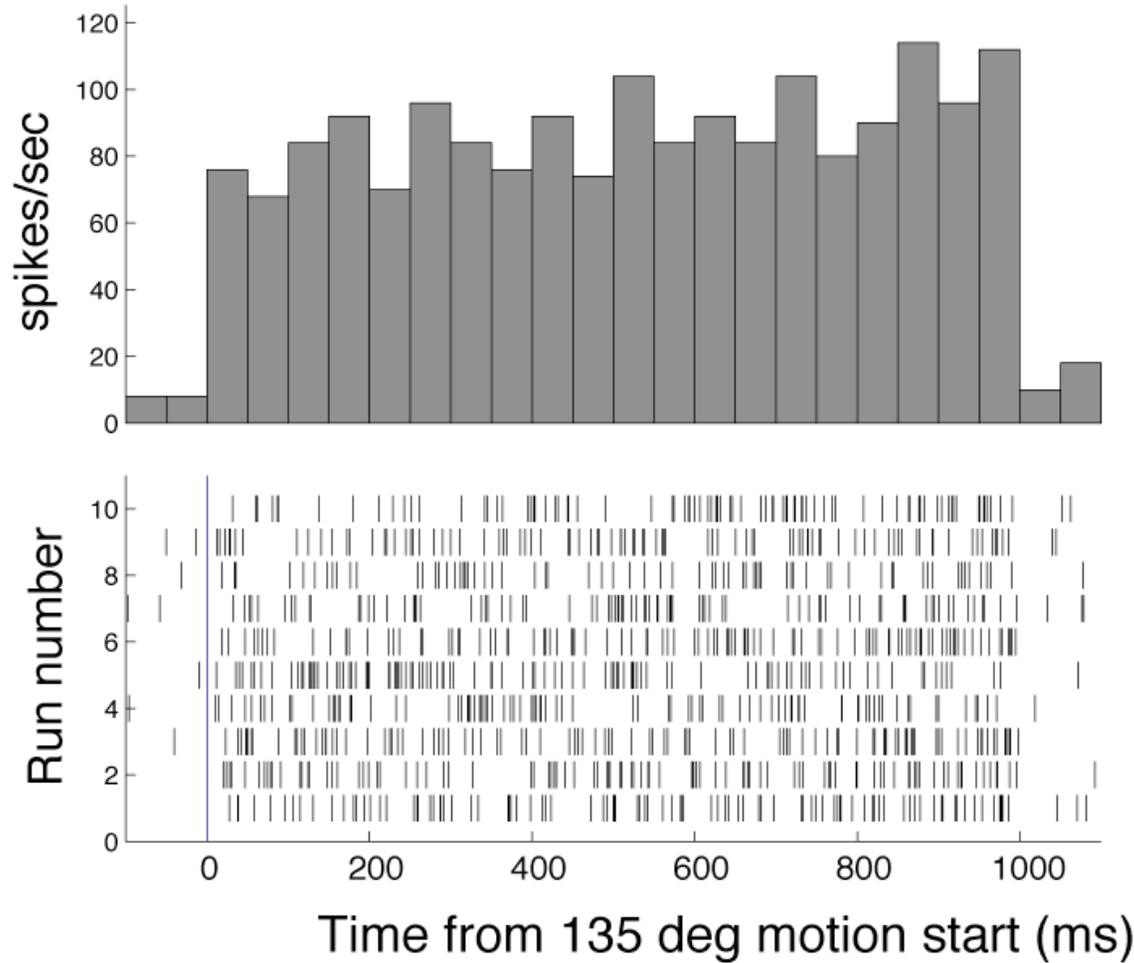
"Post-stimulus spike histogram"

"Spike rasters"

What is a key analysis parameter here?

What are key underlying assumptions that allow us to collapse the 10 trials together?

"Post-stimulus spike histogram"

"Spike rasters"

If you compute a histogram for each of your conditions, you get this…

Effect of each condition on mean firing rate

mean over what?

Matlab project3 due a week from Tuesday

Example of quantitative neurophysiology: orientation tuning a neuron in primary visual cortex (area V1) of the monkey.

A

B

Function fit to the average responses

f (Hz)

s (orientation angle in degrees)

Figure ... ey.
A ba ... es.
The ... are
and ... is
indic ... ht
bar f ... as
a function of the orientation angle of the light bar stimulus. The curve is a fit using
the function 1.14 with parameters $r_{max} = 52.14$ Hz, $s_{max} = 0°$, and $\sigma_f = 14.73°$. (A
adapted from Wandell, 1995, based on an original figure from Hubel and Wiesel,
1968; B data points from Henry et al., 1974).)

One of our overarching goals is to teach you how these kind of plots are produced.

You will do all the steps yourself!

From Dayan, Peter, and L. F. Abbott. *Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems*. MIT Press, 2001. © Massachusetts Institute of Technology. Used with permission.

Course 9.17: Brain Laboratory, Brain and Cognitive Sciences

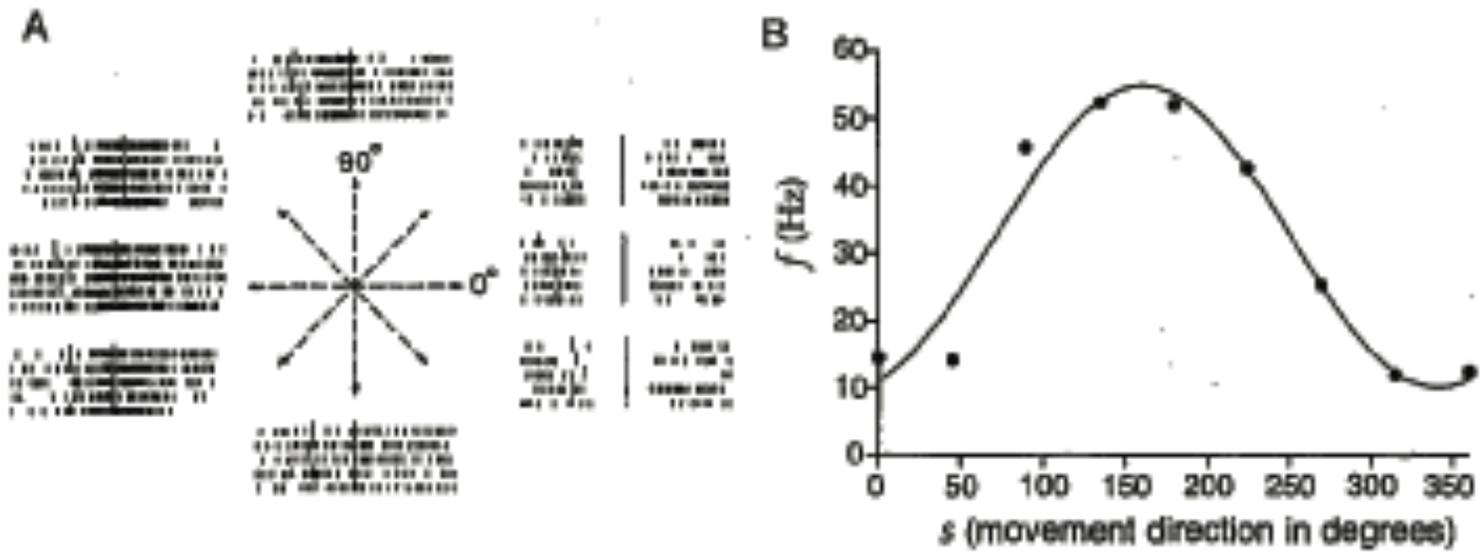# 'Direction-of-reach' tuning curve for a neuron in primary motor cortex (area M1) of the monkey.

Figure 1.6 (A) Recordings from the primary motor cortex of a monkey performing an arm-reaching task. The hand of the monkey started from a central resting location, and reaching movements were made in the directions indicated by the arrows. The rasters for each direction show action potentials fired on five trials. (B) Average firing rate plotted as a function of the direction in which the monkey moved its arm. The curve is a fit using the function 1.15 with parameters $r_{max} = 54.69$ Hz, $r_0 = 32.34$ Hz, and $s_{max} = 161.25°$. (A adapted from Georgopoulos et al., 1982, which is also the source of the data points in B.)

From Dayan, Peter, and L. F. Abbott. *Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems*. MIT Press, 2001. © Massachusetts Institute of Technology. Used with permission.

Inferotemporal Face Cell
Desimone et al. 1984

Can we make a tuning curve?

No Color

2.5°

5°
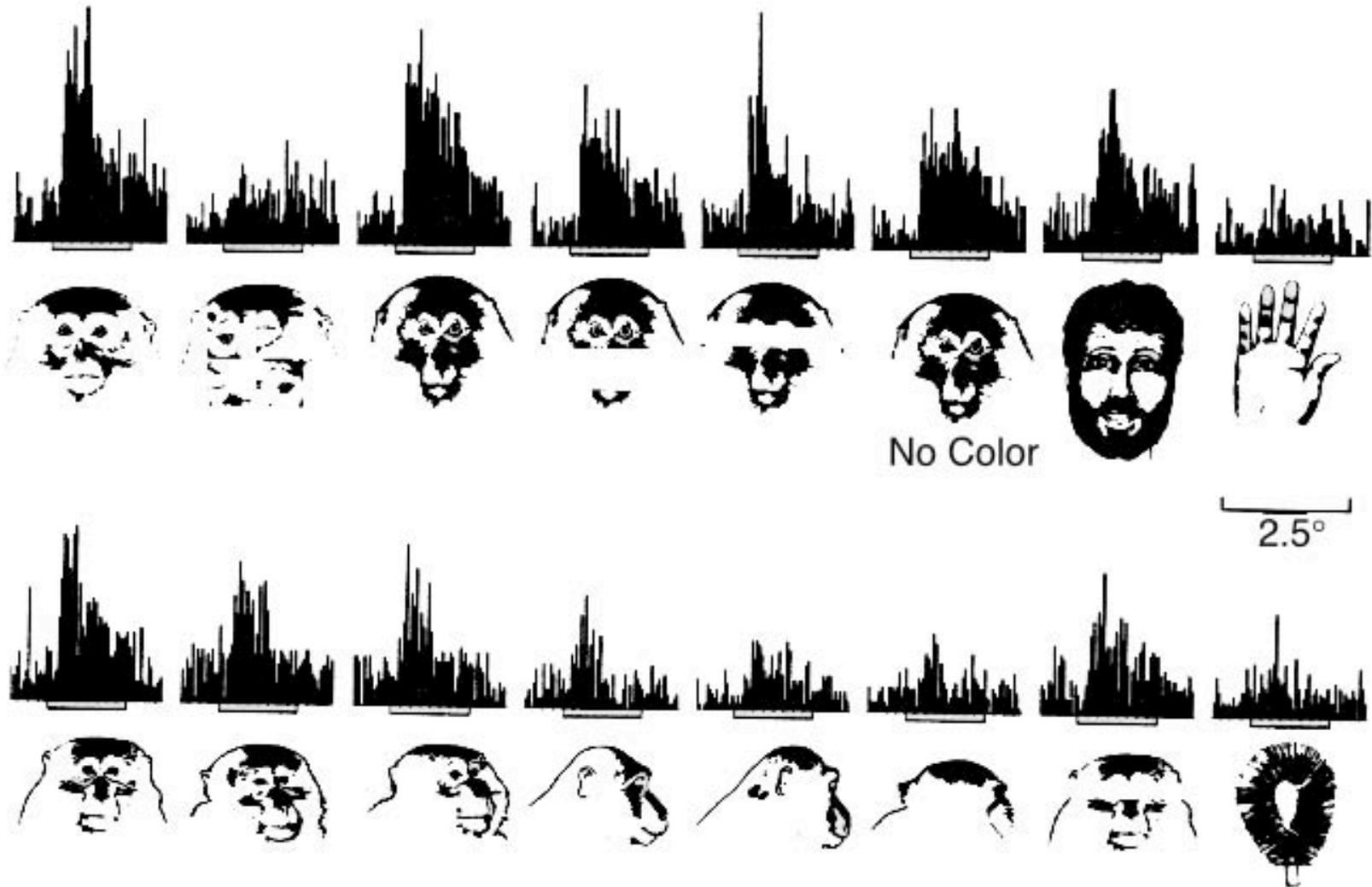
R Desimone, TD Albright, et al. "Stimulus-Selective Properties of Inferior Temporal Neurons in the Macaque."
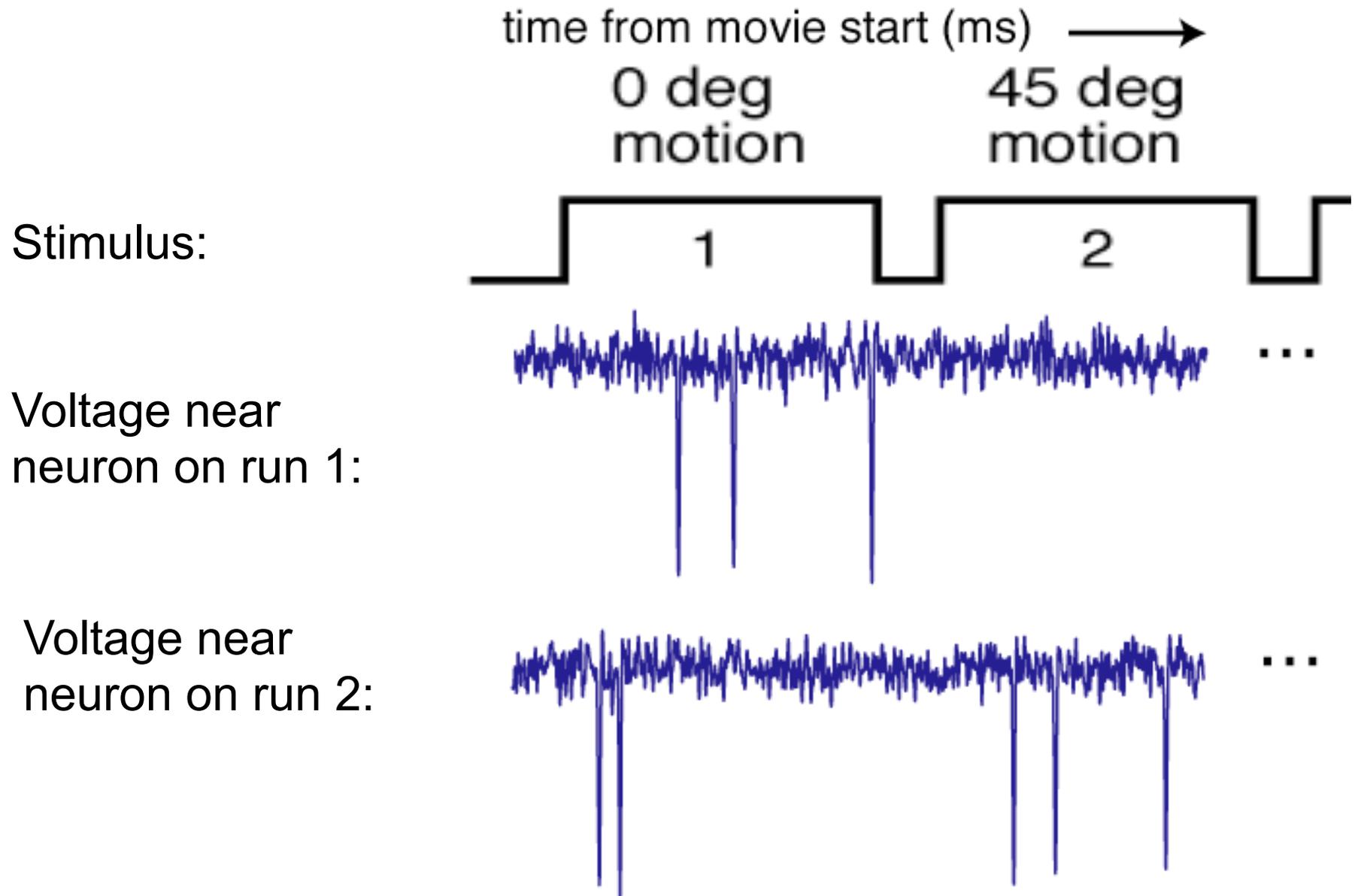*The Journal of Neuroscience* 4, no. 8 (1984): 2051-62. Available under Creative Commons BY-NC-SA.

Tuning curves: what are they good for?

- Show the data (nice summary)

- Describe trends in the data (function fit)

- Predict response to other stimuli ?

- Describe the neuron's role in behavior ???

Tuning curves: downsides

- Emphasize mean firing rates. Msec-scale timing of individual spikes is ignored

- Not everything we are interested in can be plotted along a single axis

Neuronal spiking is <u>stochastic</u>. Why?

time from movie start (ms) ⟶

0 deg
motion

45 deg
motion

Stimulus:

1

2

Voltage near
neuron on run 1:

...

Voltage near
neuron on run 2:

...

Lecture overview

- What hypothesis to test in the fly?
- Quantitative data collection
- **Visual physiology conventions ("Methods")**
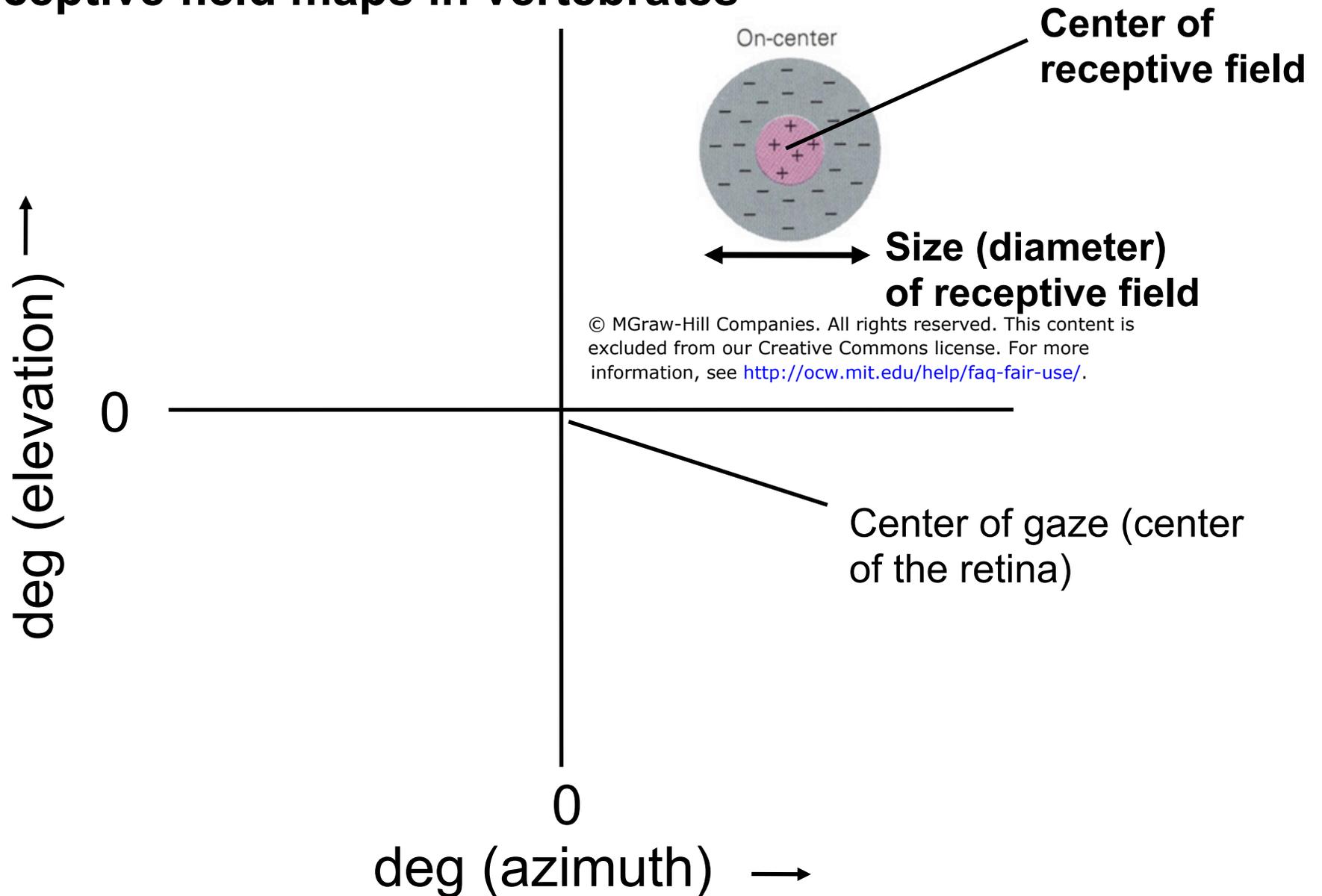
Standard units of visual stimuli

Screen distance: 1.5 meters

Distance on retina:
1 millimeter

3.5-degree
angle

Distance on screen:
89 millimeters

Rays of light
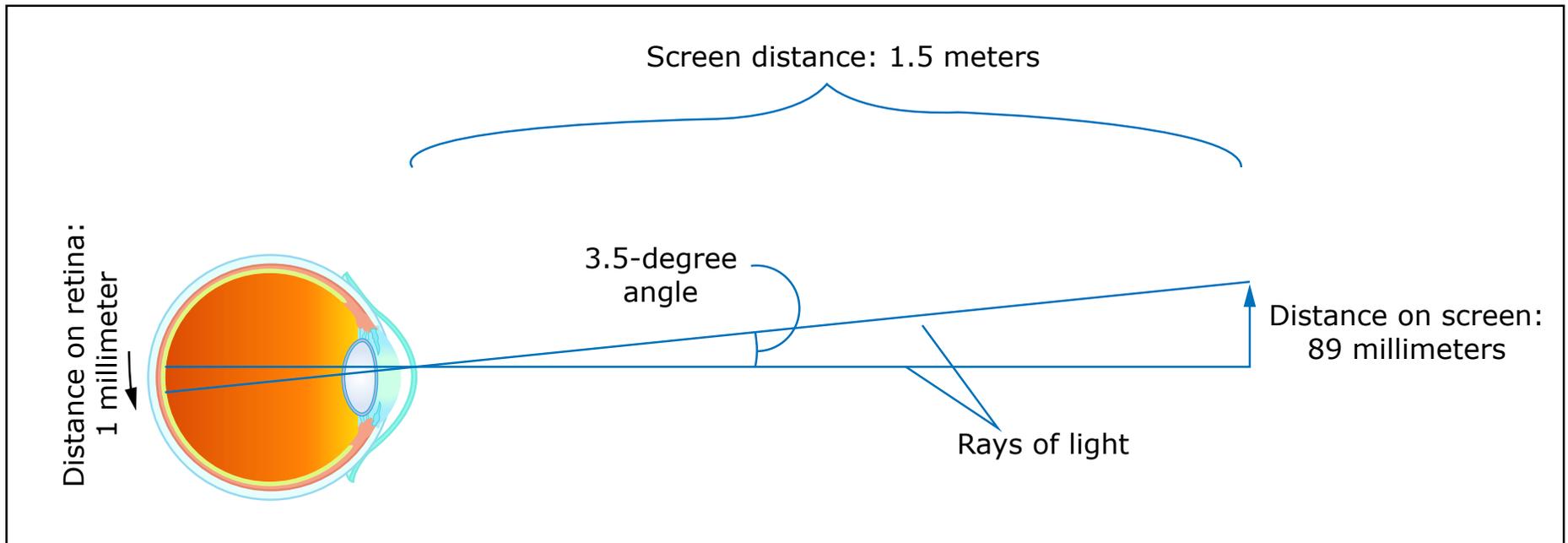
Image by MIT OpenCourseWare.

Stimulus size: degrees of visual angle (deg)

E.g. "The white square subtended approximately 4 deg x 4 deg of visual angle"

Speed of motion: degrees of visual angle covered per unit time (deg/sec)

E.g. "The white square was moved from left to right at a speed of 40 deg/s."

Standard units of visual stimuli: receptive field maps in vertebrates

On-center

Center of receptive field

Size (diameter) of receptive field

deg (elevation) →

0

Center of gaze (center of the retina)

0

deg (azimuth) →

Standard units of visual stimuli:
receptive field map

Receptive field
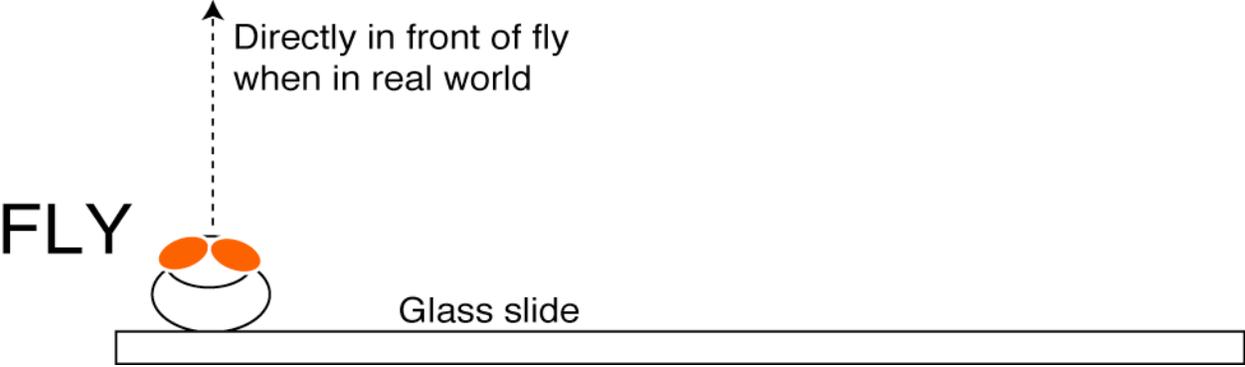**of a neuron**

deg (elevation) →

0

Center of visual axis of
the fly

0

deg (azimuth) →
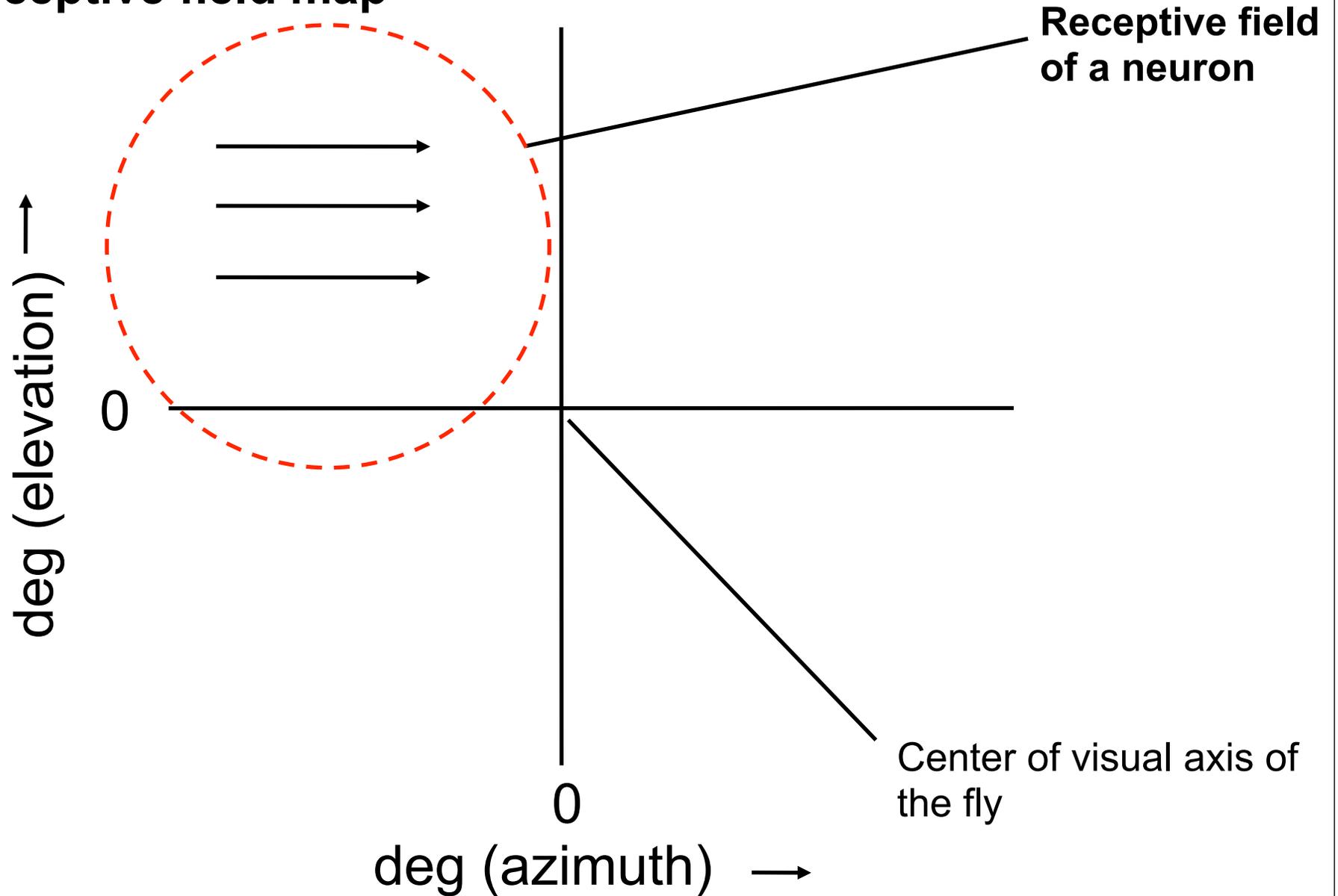
motion RF of the H1 neuron

your monitor?
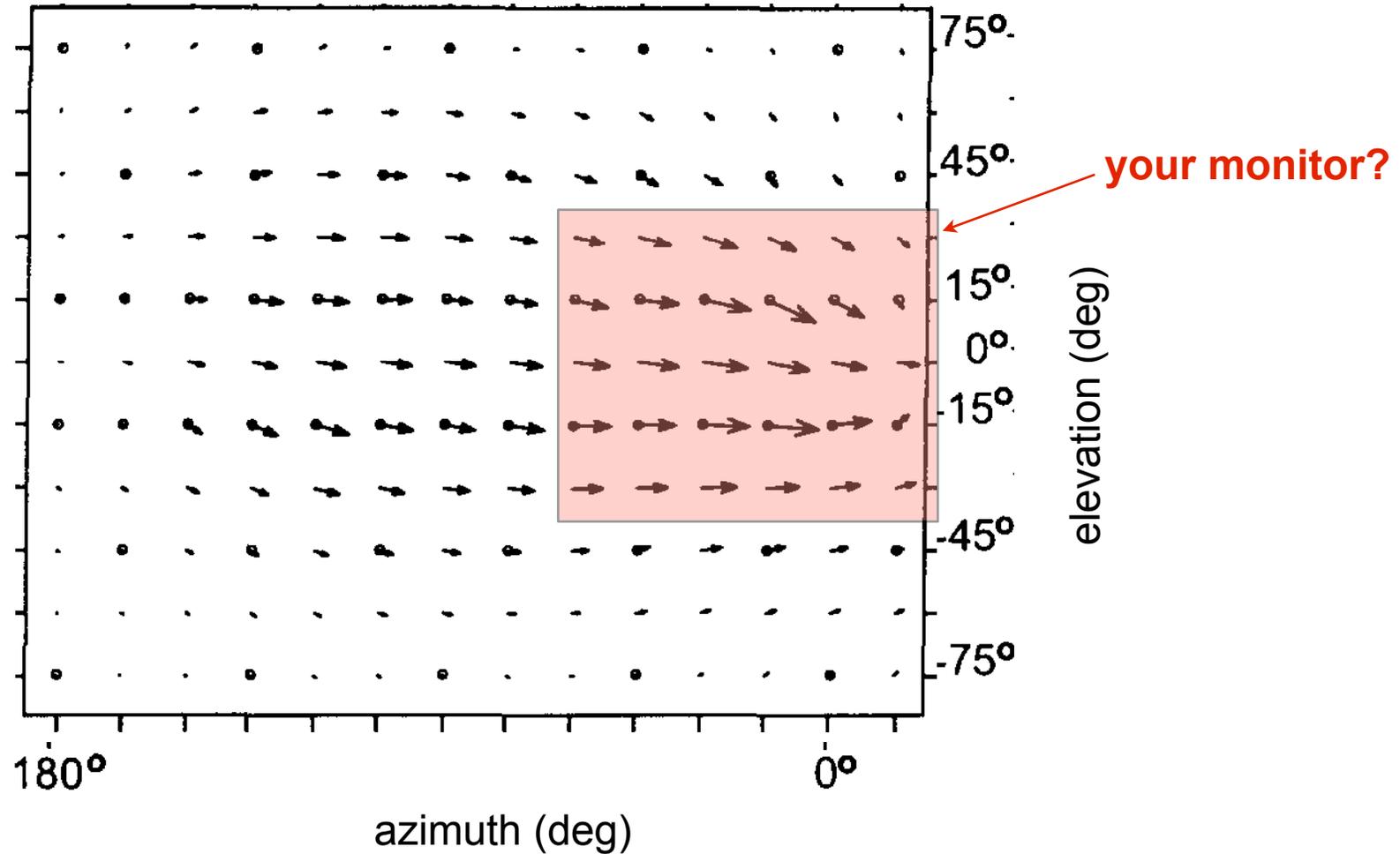
Courtesy of Elsevier, Inc., http://www.sciencedirect.com. Used with permission.

Krapp and Hengstenberg, Vision Res. (1997)

Fly visual field: state your conventions!

Video monitor

regressive motion

progressive motion

FLY

Video monitor

'above'

'behind'   'in front'

'below'

Directly in front of fly
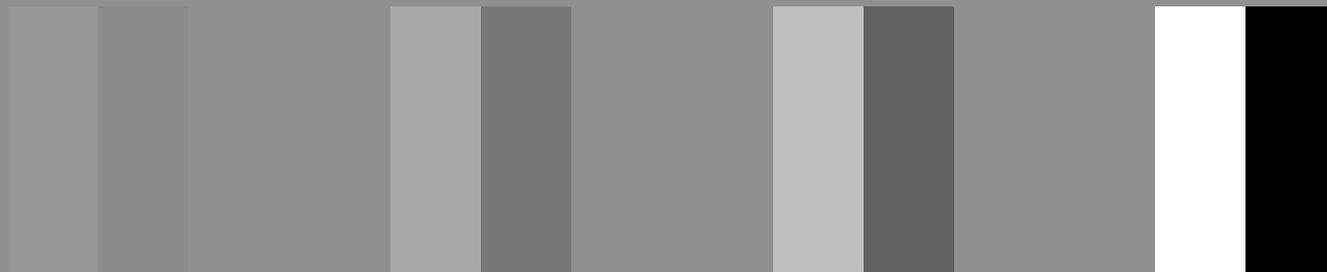when in real world

FLY

Glass slide

Luminance

31
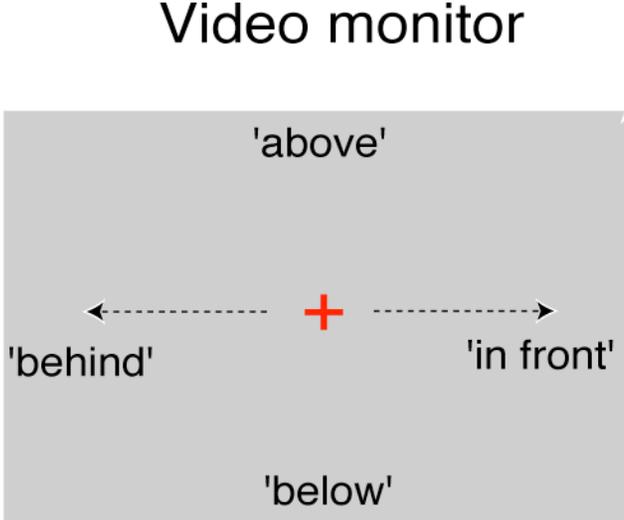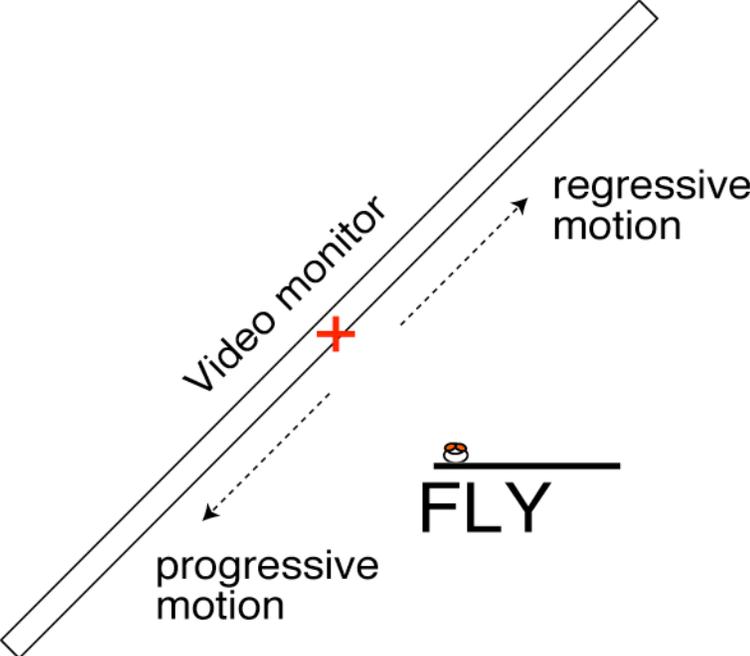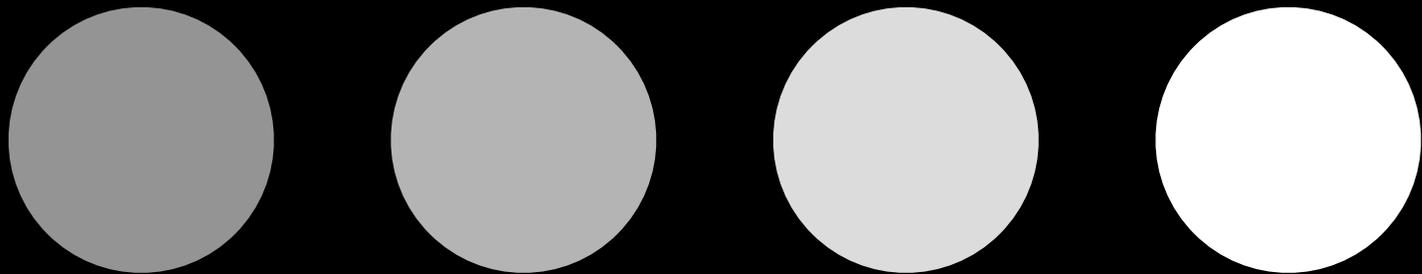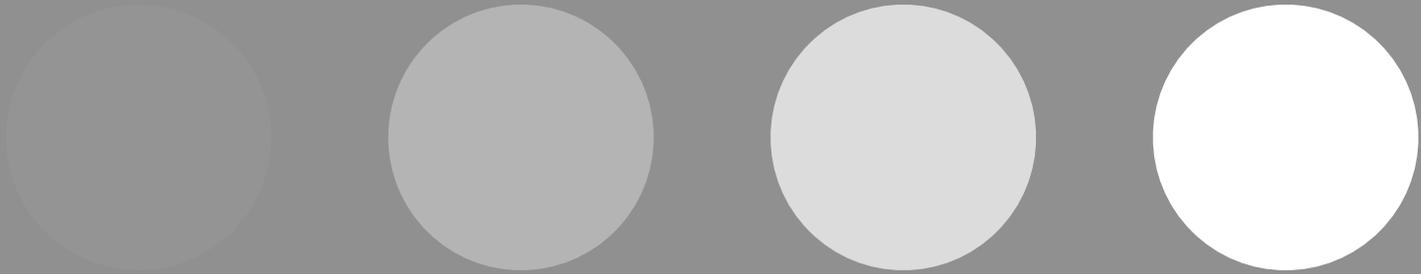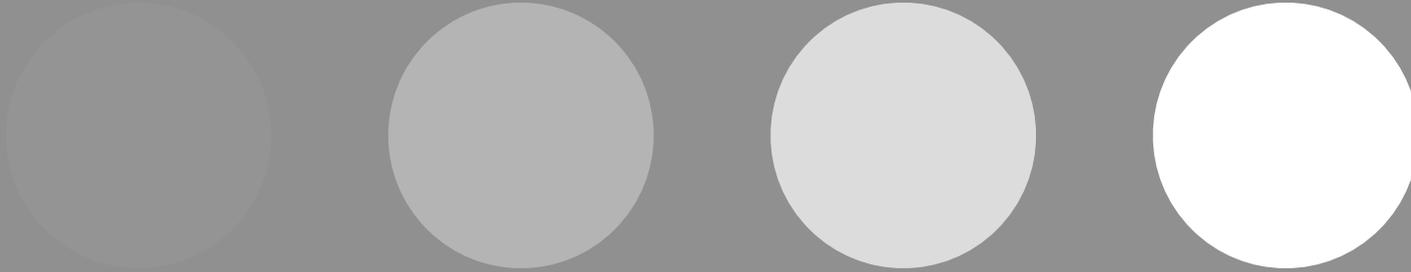
Luminance

Contrast

Basic units of visual stimuli

- luminance: amount of light (~photons) emitted from a particular area per unit time (units: candela/m^2)

- contrast: range of luminance relative to the total luminance (e.g. Michelson contrast = (Lmax - Lmin) / (Lmax + Lmin))

For your lab report:

assume that your display monitor has:

maximum luminance of 100 cd/m^2 (full white, pixel value = 255 in Matlab matrix)

minimum luminance of 1 cd/m^2 (deepest black, pixel value = 0 in Matlab matrix)

9.17 Systems Neuroscience Lab

Spring 2013