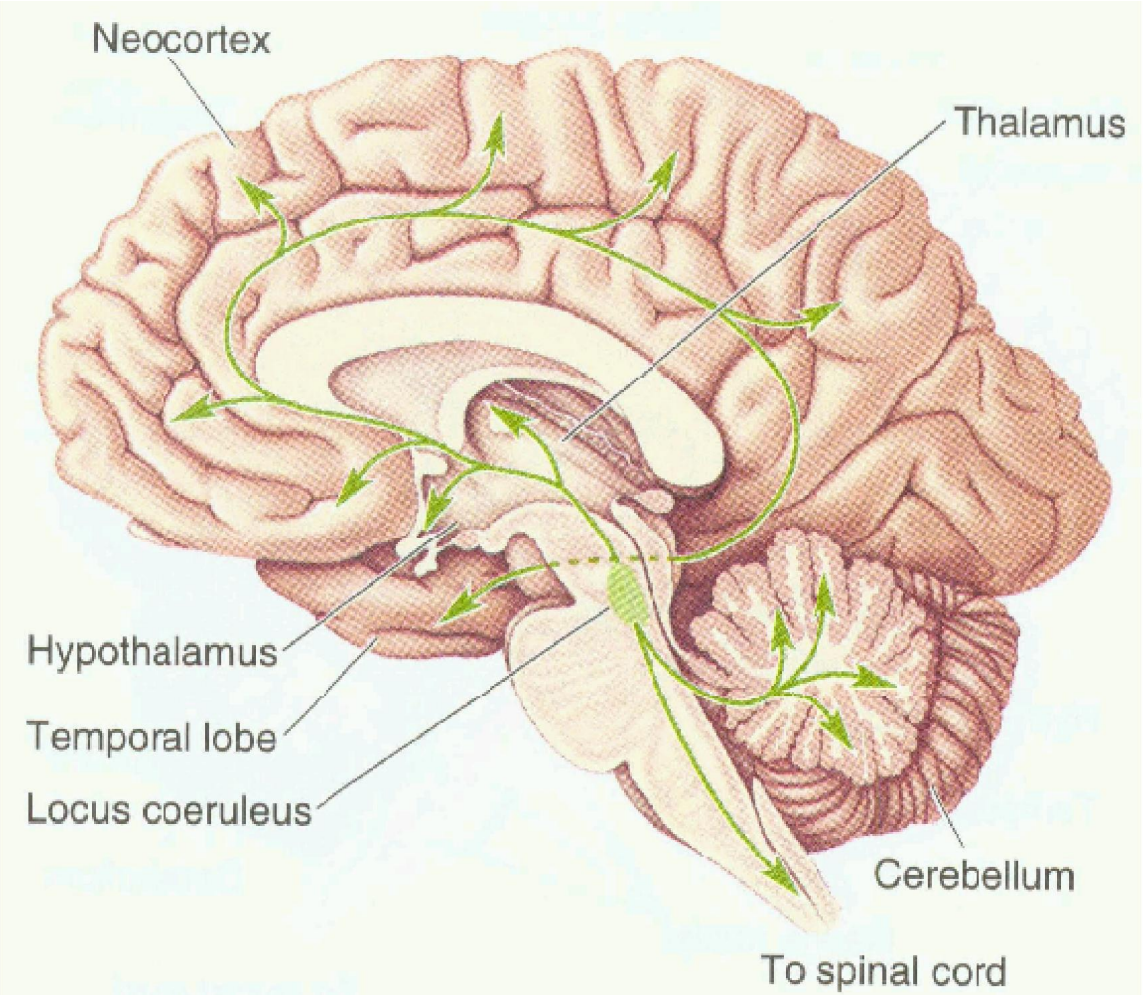


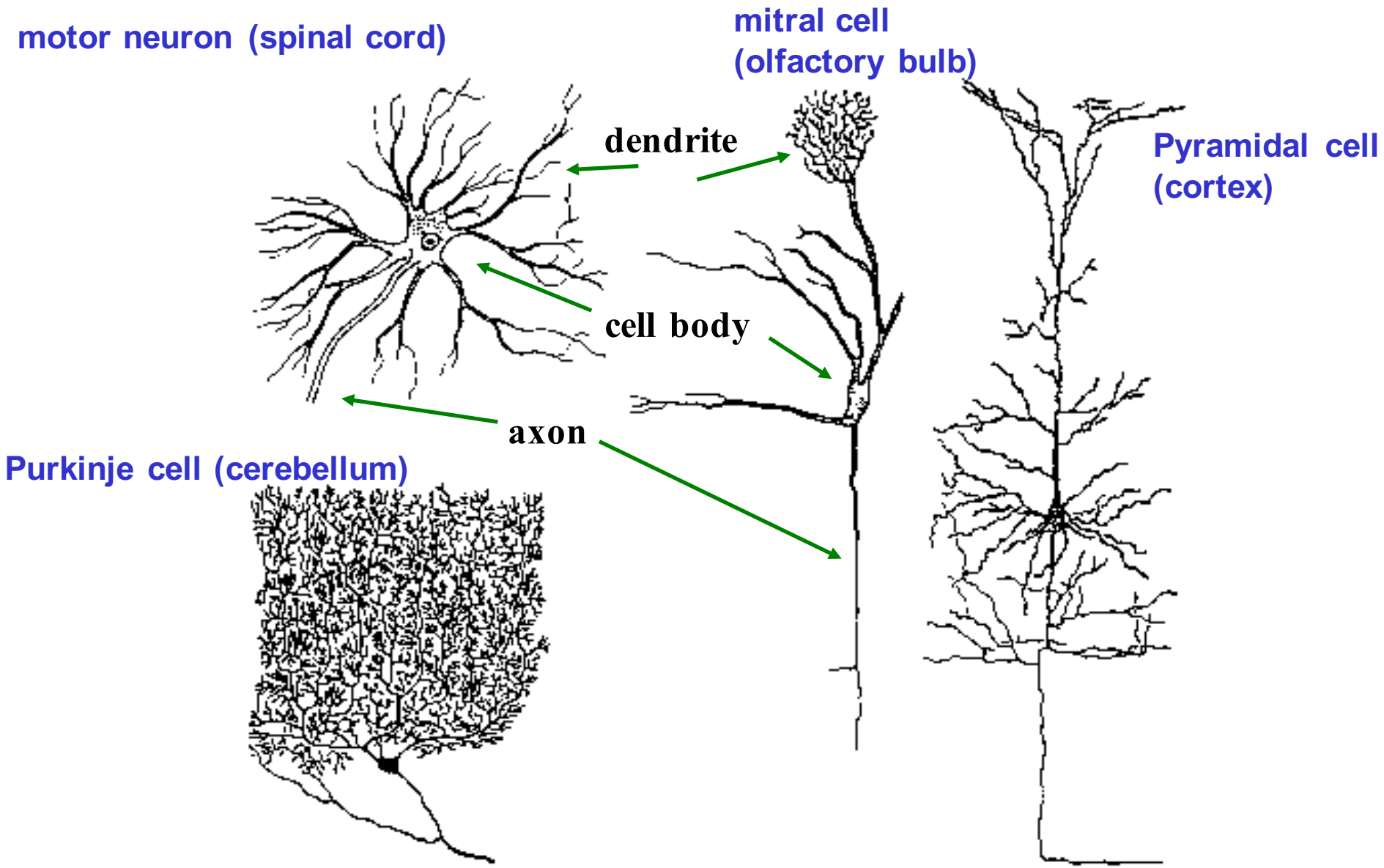
from *Neuroscience: Exploring the Brain* by M.F. Bear, B.W. Connors, and M.A. Paradiso, 2001

10^{11} neurons

(10^5 per mm^3)

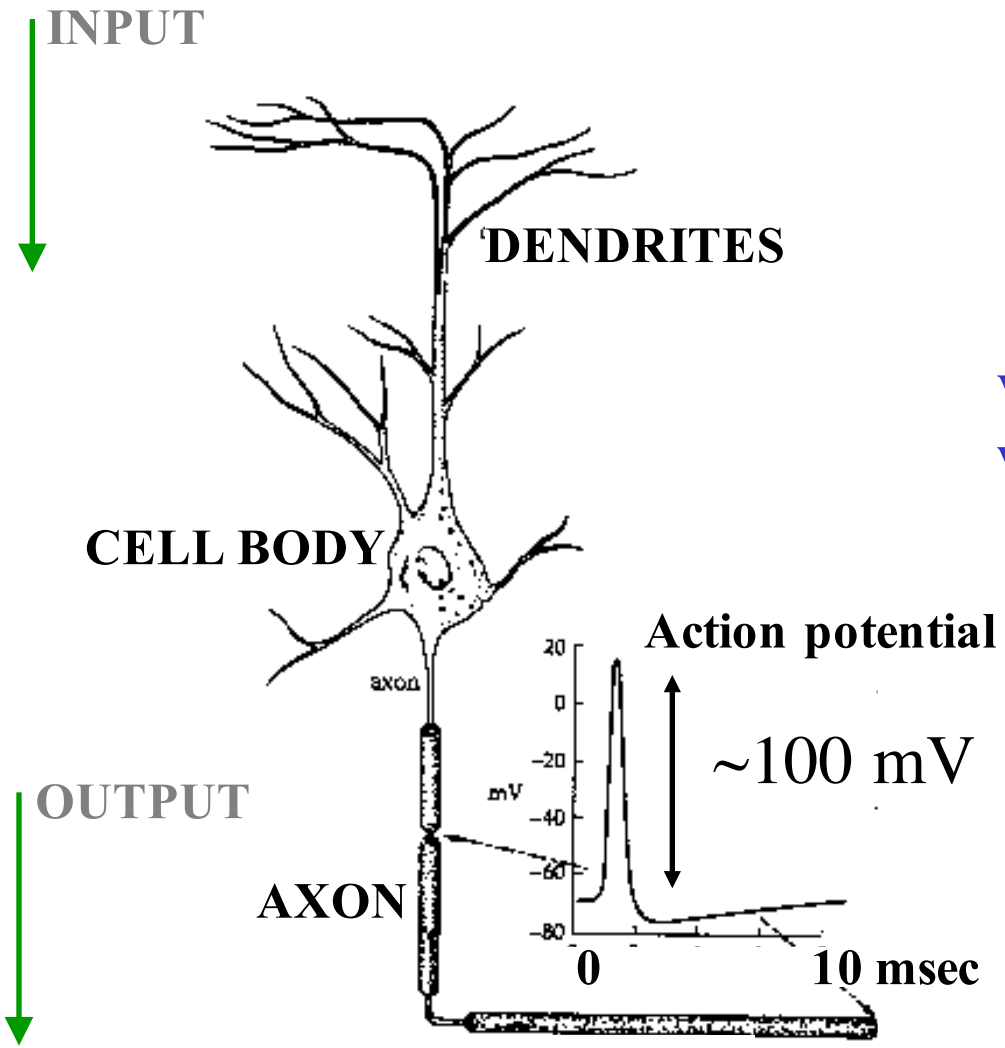
10^{15} synapses

Electrical signals come IN to dendrites, are "integrated" in cell body, result goes OUT axon



From Nicholls et al, 1992, Fisher and Boycott, 1974, Johnston and Wu, 1997

Given sufficient input, neurons "fire action potentials" – fast voltage transients

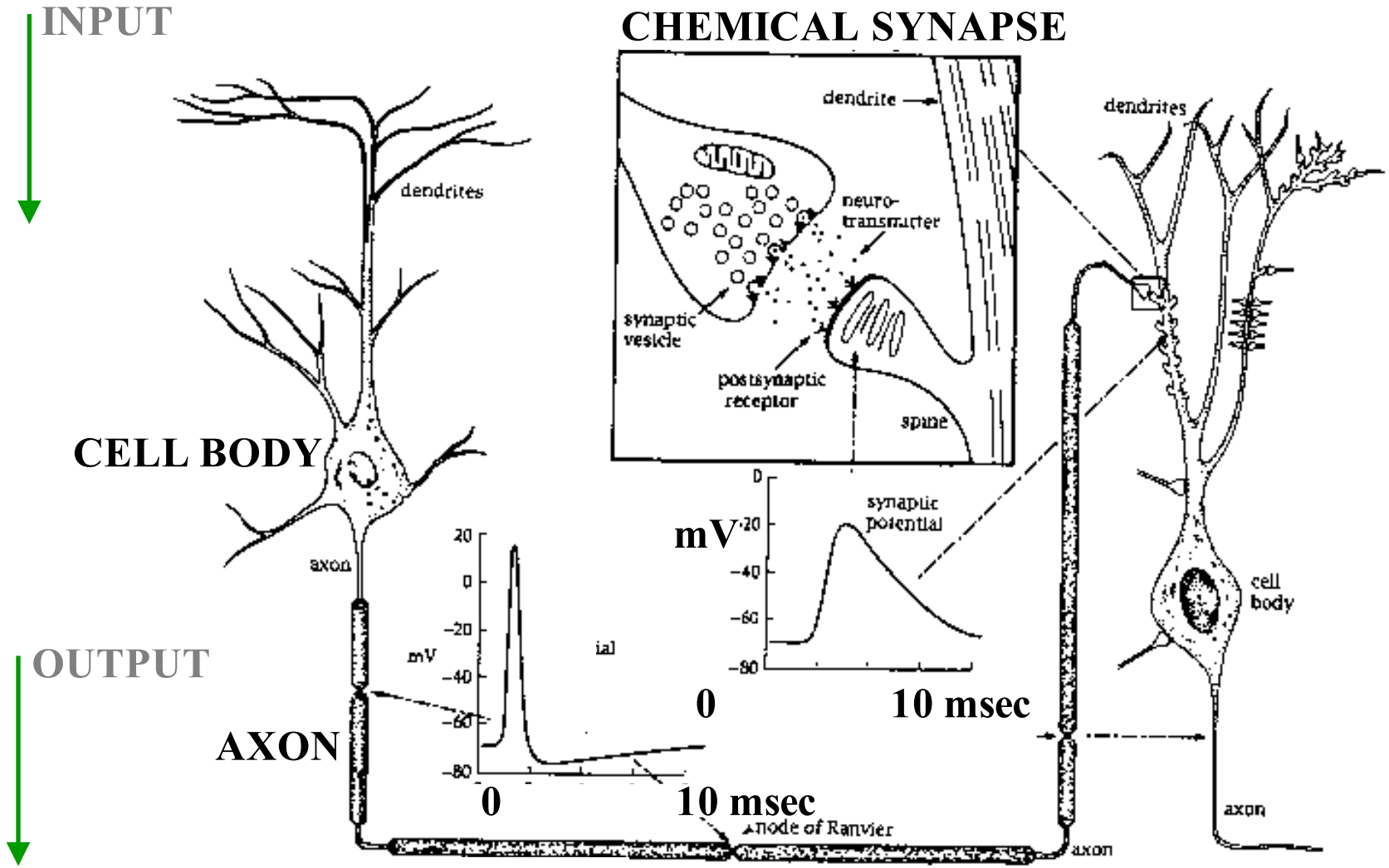


Voltage V: set by "excess charge" inside vs outside membrane (more later)

Johnston and Wu, 1997

Given sufficient input, neurons "fire action potentials" – fast voltage transients

…which are communicated to downstream neurons via synapses

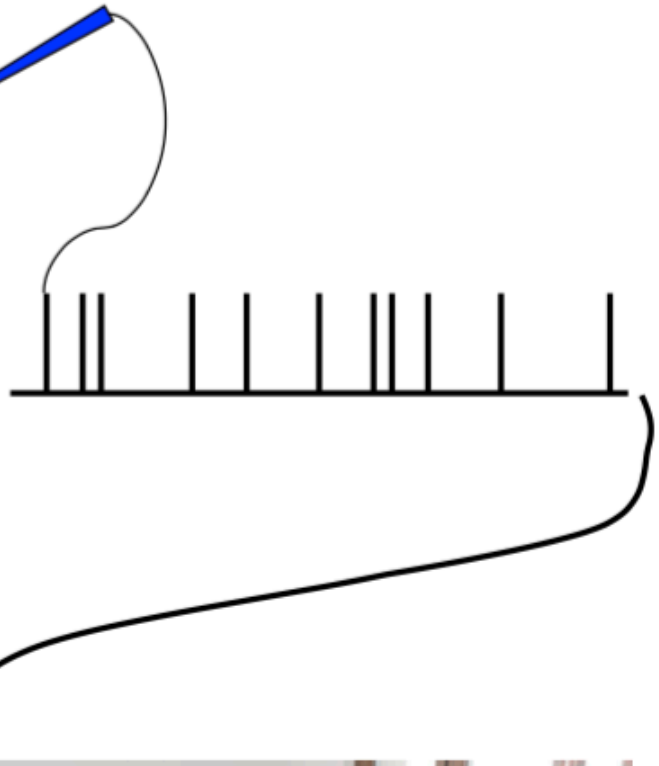


Johnston and Wu, 1997

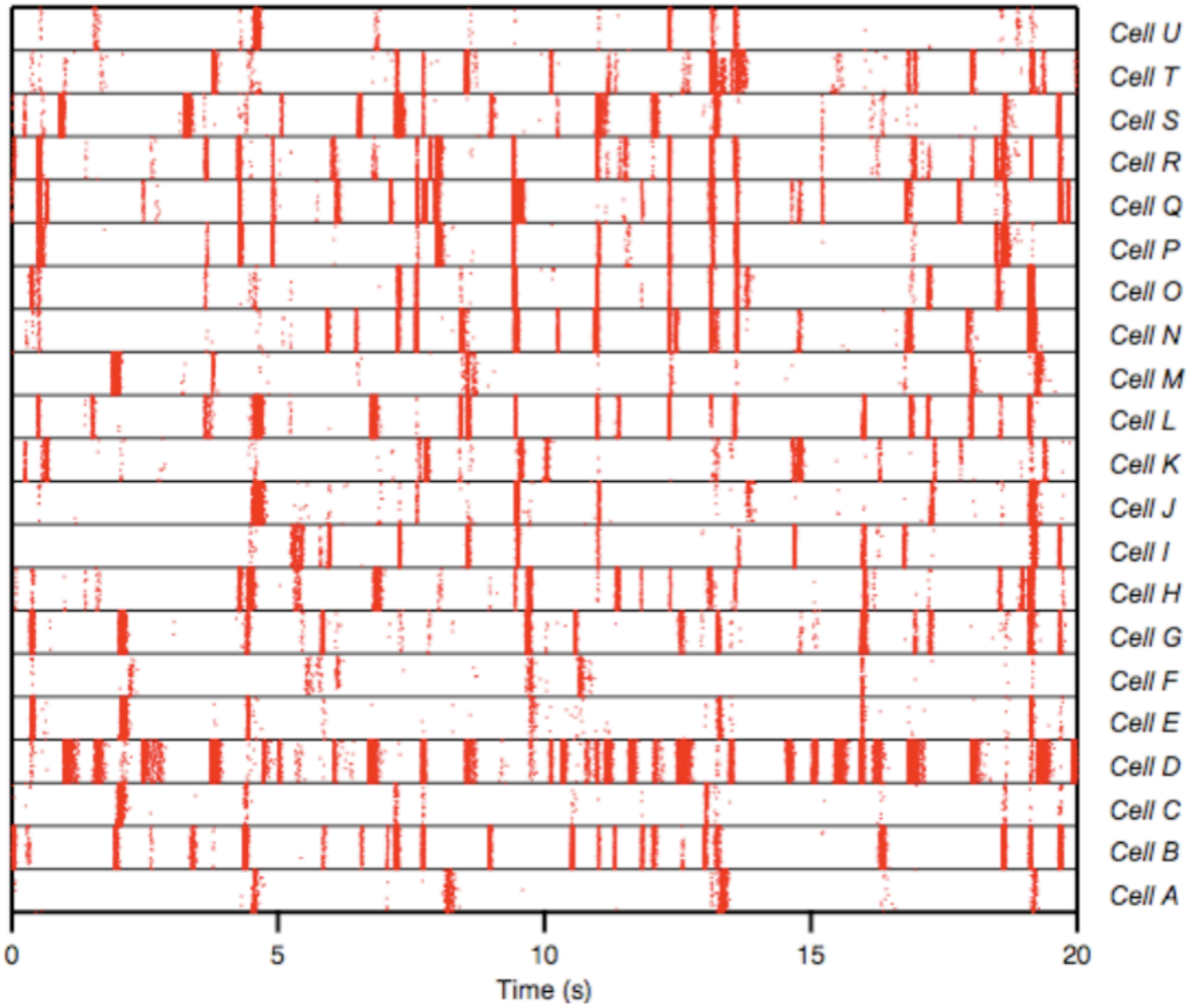
- Overview (blackboard)

- Thanks to Prof. Adrienne Fairhall for many slides, materials, and ideas!

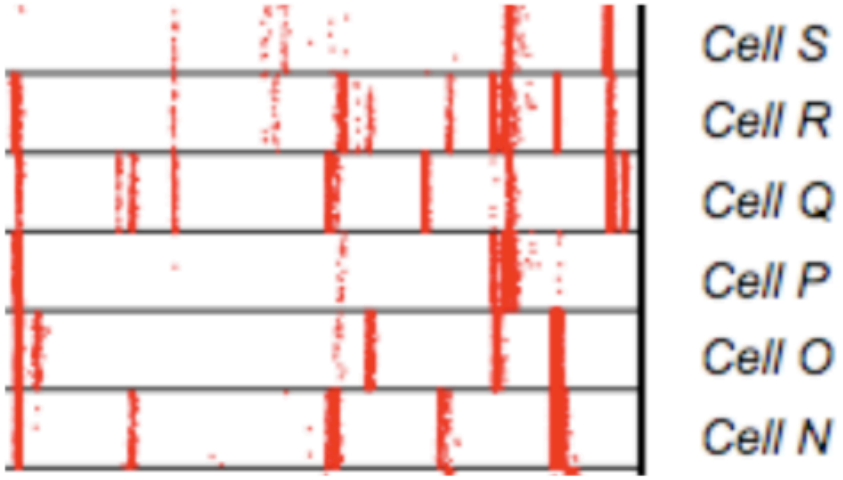
Neural coding



What is the neural code?



What is the neural code?



Encoding: how does a stimulus cause a pattern of responses?

- what are "responses" and what are their characteristics?
- how much is deterministic and how much stochastic?
- neural models:
  what takes us from stimulus to response;
  descriptive and mechanistic models, and the relation between them.

Decoding: what do these responses tell us about the stimulus?

What are these neural signals trying to say?

- Implies some kind of decoding algorithm
- How do we evaluate how good our algorithm is?

Neural coding

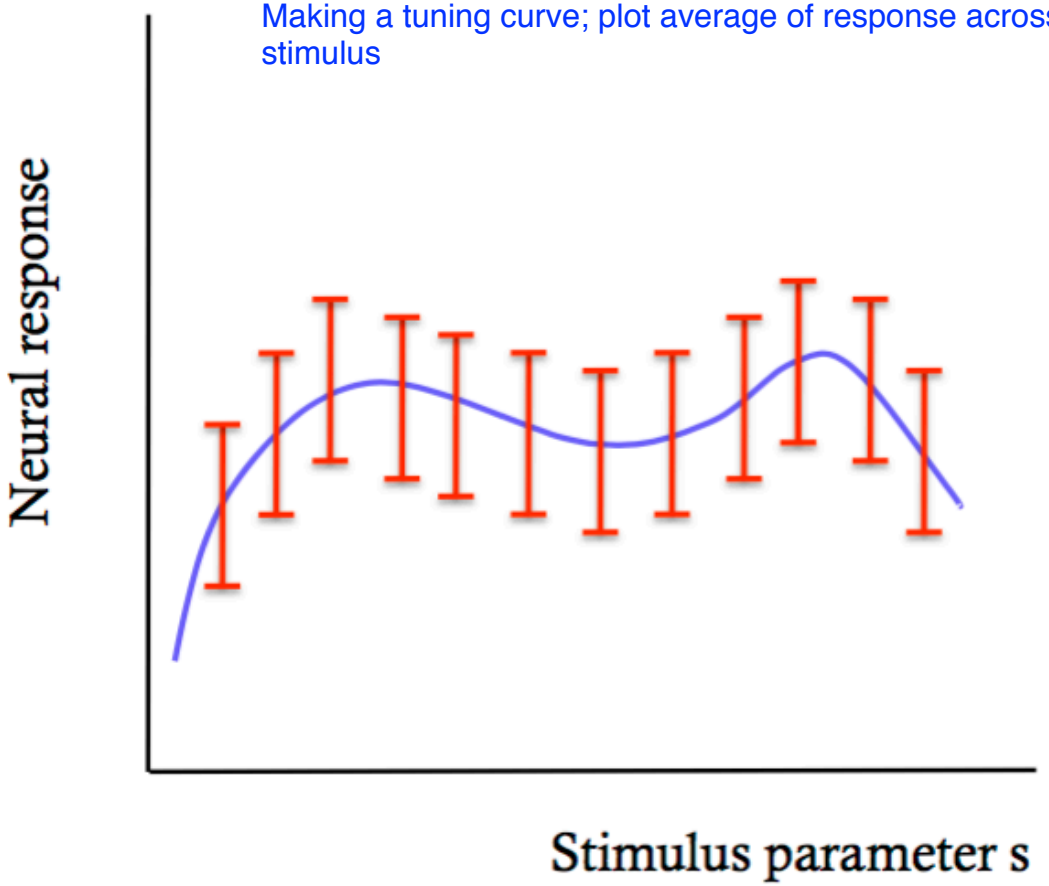
More generally, we are interested in determining the relationship:

P(response | stimulus) *encoding*

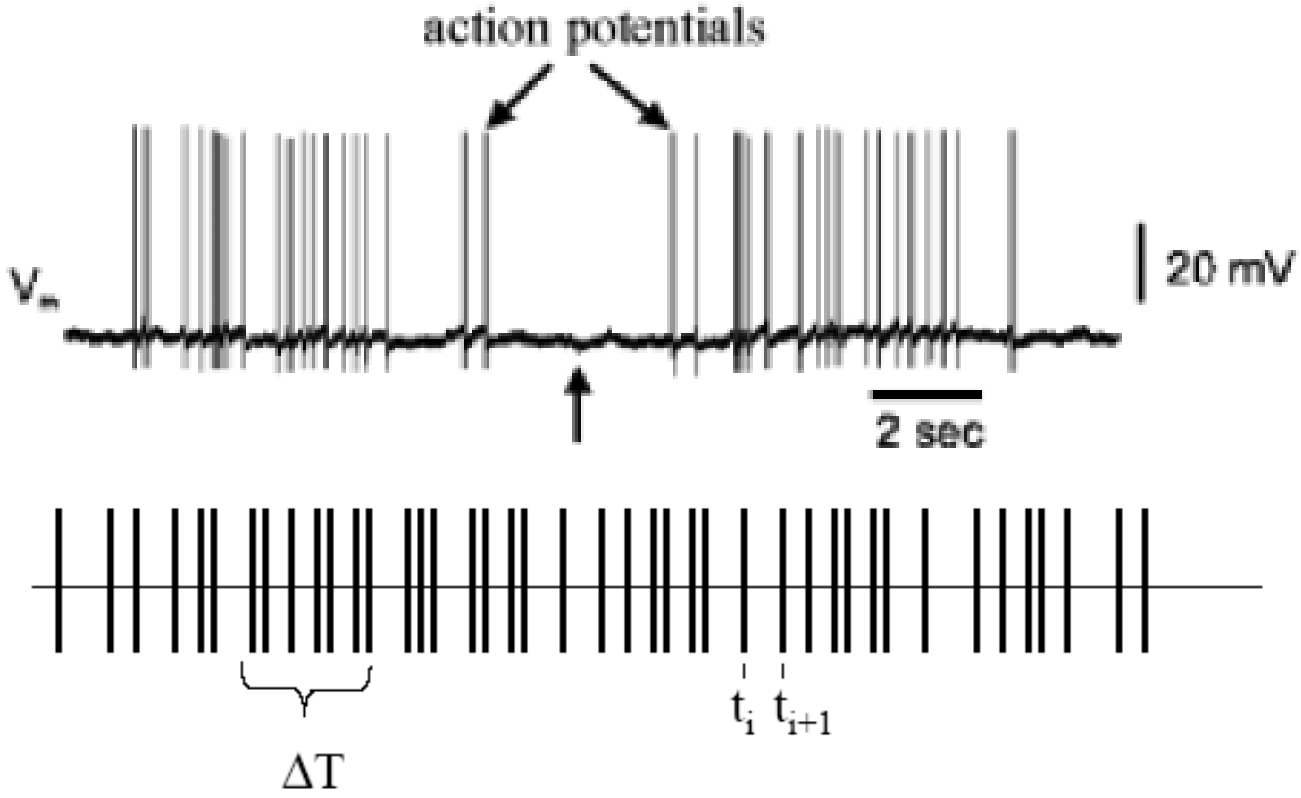
P(stimulus | response) *decoding*

Neuronal representation of information

Making a tuning curve; plot average of response across multiple trials with a given stimulus



Simplest definition of neural response: *firing rates*



Firing rate = (# spikes) / (Delta T)

(Other possibilities: spike timing, synchrony among multiple spikes, …)

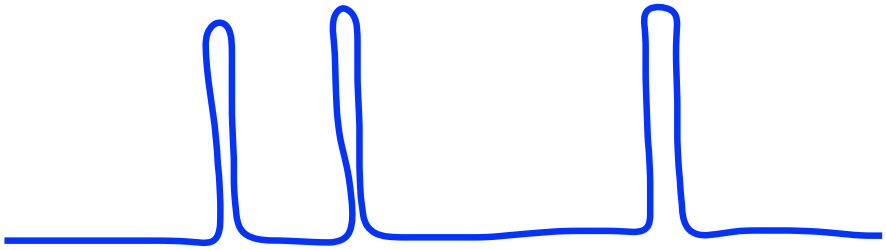
(Board … definition of delta function)

Delta Functions

Delta fn = lim Delta t —> 0 {1/dt if -dt/2 <= t <= dt/2
0 otherwise
}

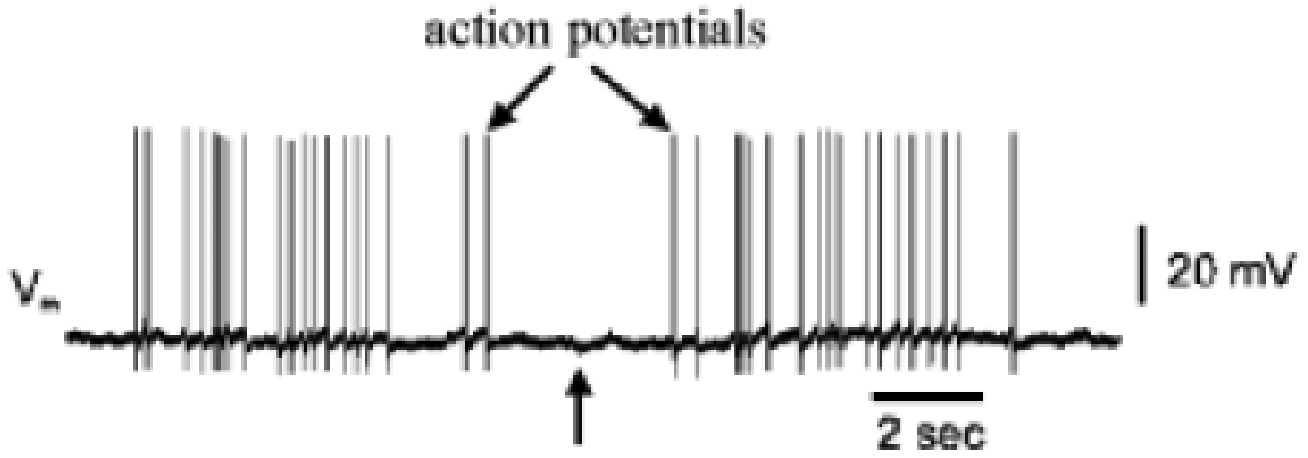
Integral of Delta FN = 1 as long as definite integral contains the spike

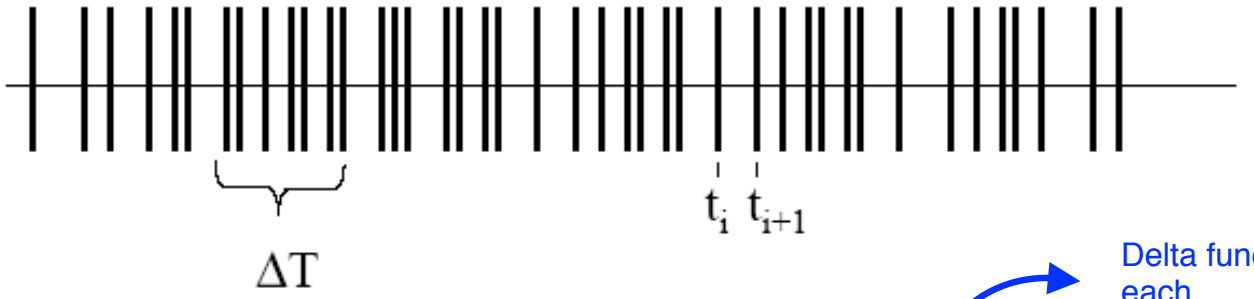
Spike train = p(t) = sum of a bunch of spikes that occur at time t0, t1, etc



# of spikes in time interval [start, end] = integral of p(t) from start to end

Spike rate = # spikes / length of time interval





David Tank

SPIKE TRAIN $$\rho(t) = \sum_{t_i} \delta(t - t_i)$$

Delta functions; represent single spike each

FIRING RATE $$r(t) = \frac{1}{\Delta T} \int_{t}^{t+\Delta T} \rho(t) dt$$

number of spikes

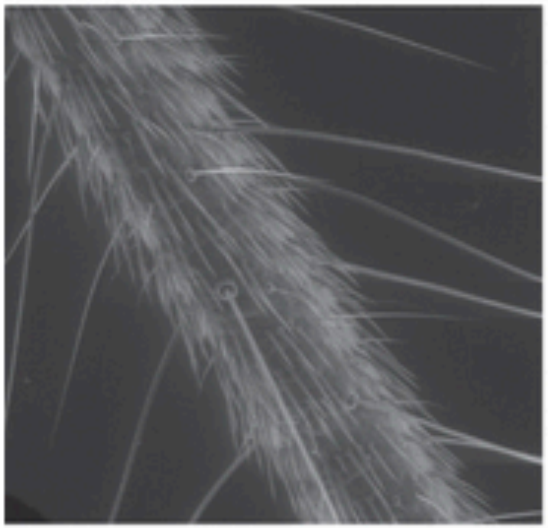
Starting "simple:"
Stimulus ENcoding in the cricket cercal system

electrodes attached to mechanoreceptors in cricket legs

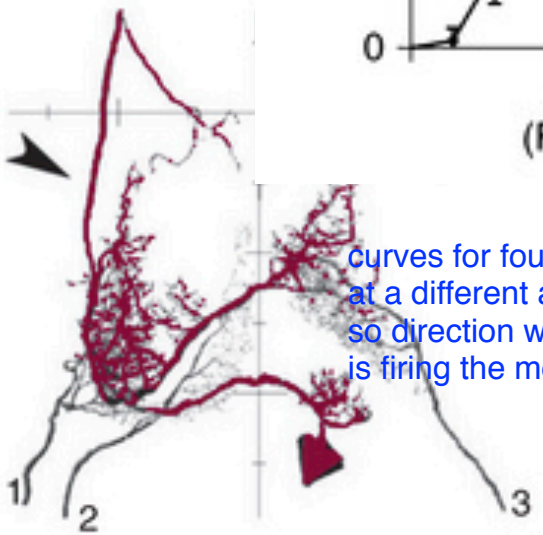
Response = firing rate

Stimulus = wind direction

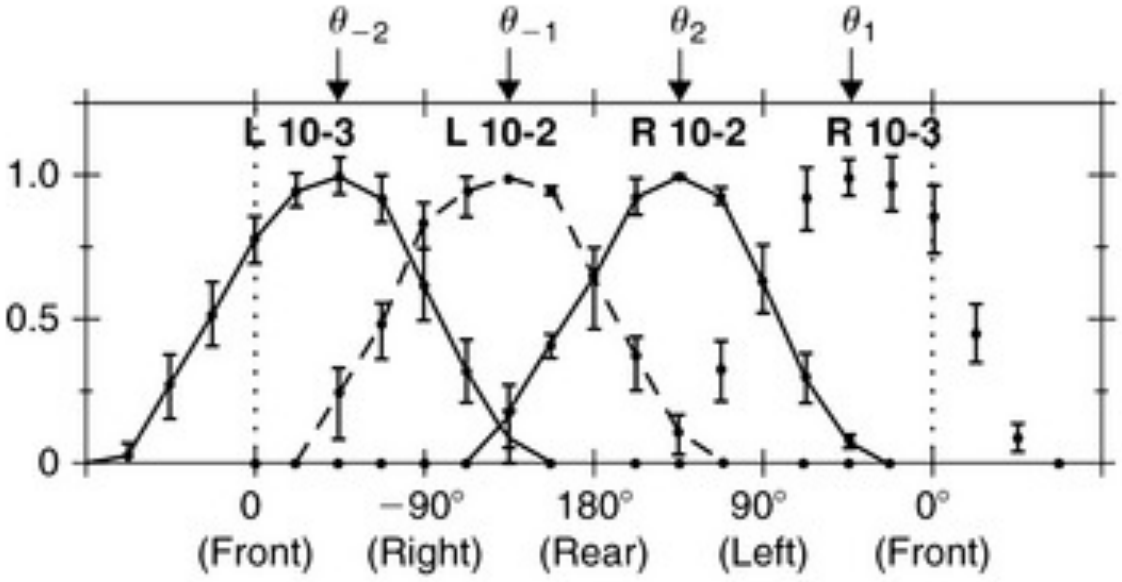
(A)



(B)



(C)

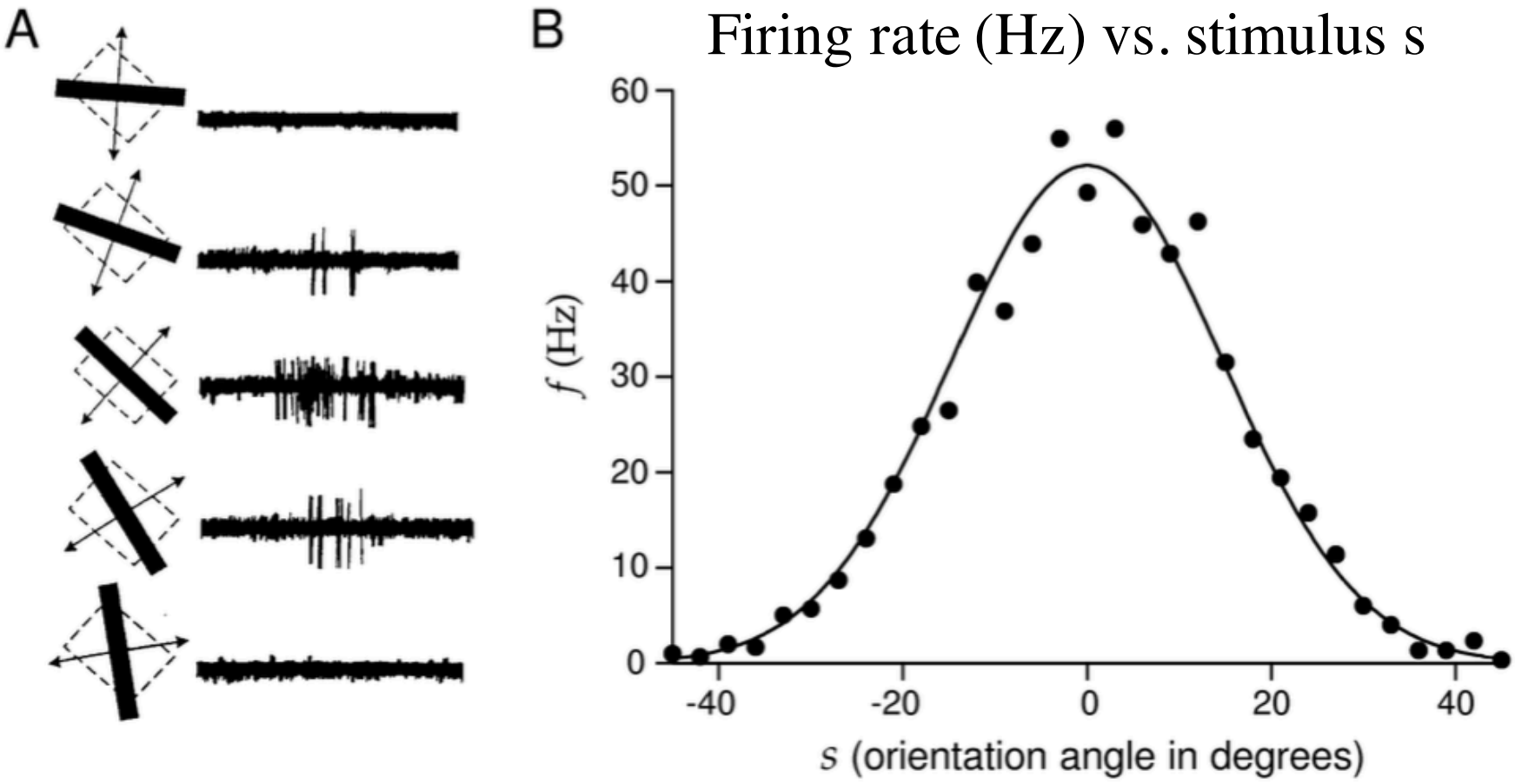


curves for four separate different neurons, where each peaks at a different angle theta. Essentailly develops a compass/cardinal directions so direction wind is coming from can be determined by which neuron is firing the most and whihc arent firing very much

26.1, Math. for Neurosci.; Miller et al '91

Receptive fields and tuning curves

Tuning curve: r = f(s)



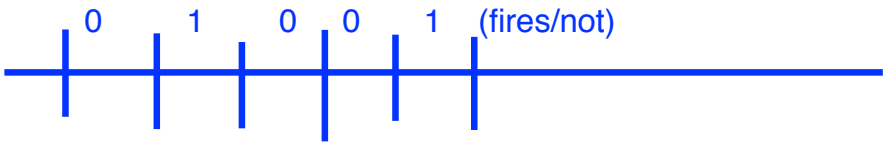
Gaussian tuning curve of a cortical (V1) neuron

(Board –
Modeling spike trains and the Poisson process
Random variables
Generating spike trains in MATLAB)

Modeling a neuron as a Poisson Process

Divide time into binds with width dt

Cell firing with a rate R, so there is a spike in each bin with probability P = R*dt



Statistics reviews

Random Variable is object X that has…
1) set of possible values {s1, s2, …, sn}
2) probablity of X being each individual vale

Realization/Trial of random variable = assigns X to one of its possible values with probability P(sj)

i.e. toss a coin values : {heads, tails}

X	tails	heads
P(X)	p	1-p

Values do not have to be discrete, can be continuous random variables with range [a,b] probability distribution p(x).

probability x element [some interval] = integral p(x) between two endpoints

Uniform random variable with range [0 1] flat line with height 1. Each choice between 0 and 1 is equally likely

Code 1: `generate_simple_spiketrain.m`

```
%Generate single spiketrain

rand('state',sum(100*clock));

nsec=1 ;
T=1;
deltat=0.001;
r=100;
p=r*deltat;
numbins=round(T/deltat);
spiketrain=round(rand(1,numbins) + (p-1/2))


figure;
imagesc(spiketrain)
…
```

(Board – Mean, variance, std dev)

Basic Sample Statistics of a Random Variable X

M samples/trials of Random Variable X

sample mean(X) = sum(values all trials of X) / M

Variances = squared deviations from sample mean

~1/M * (sum((XsingleSample - Mean(x))^2)

As M —> infinity, this will converge towards the true statistics of the thing being sampled (Law of Large Numbers)

in MATLAB, given a sample list [x1, x2, x3, .., xn]

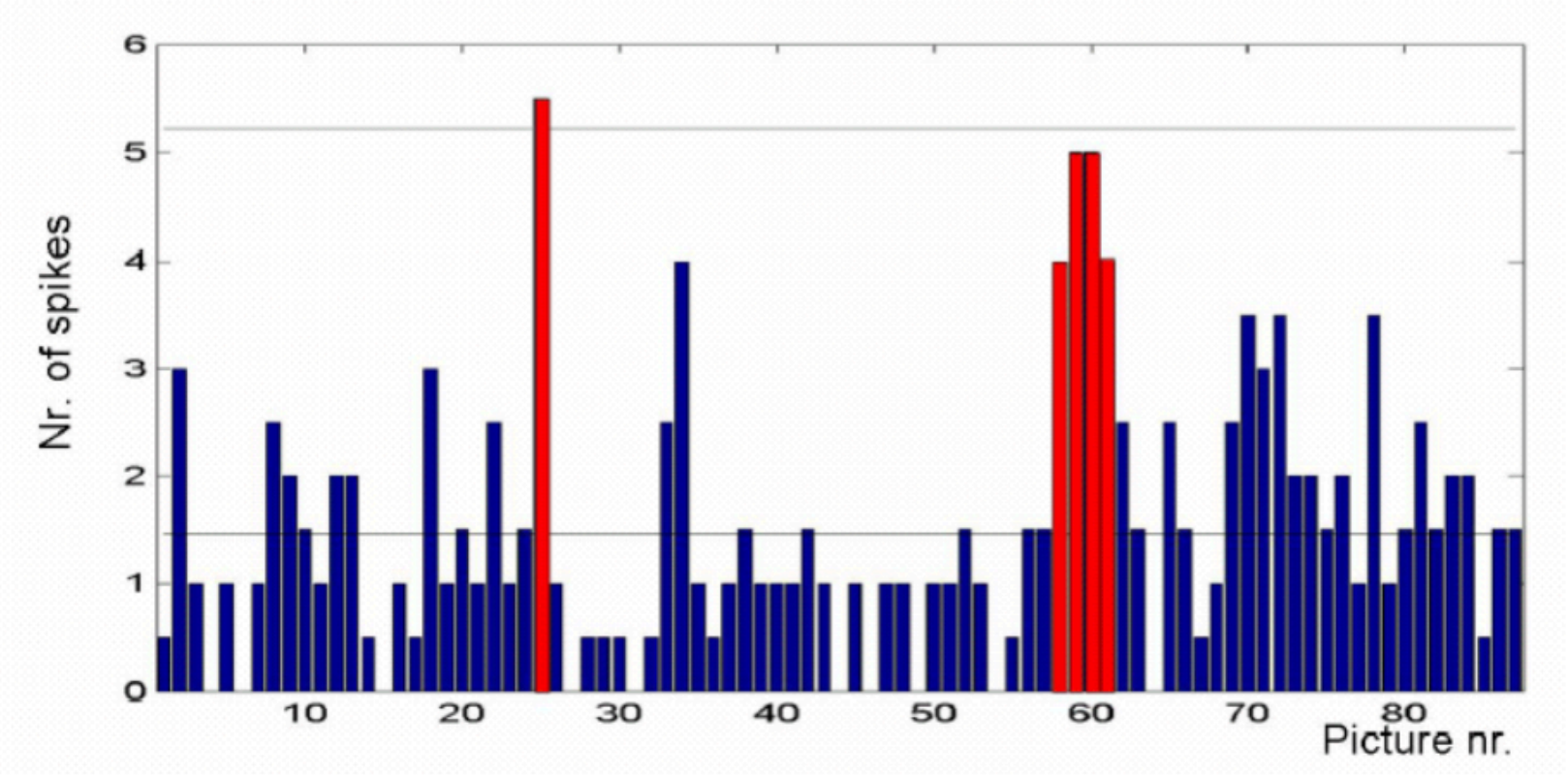
mean(sample_list)
std(sample_list)

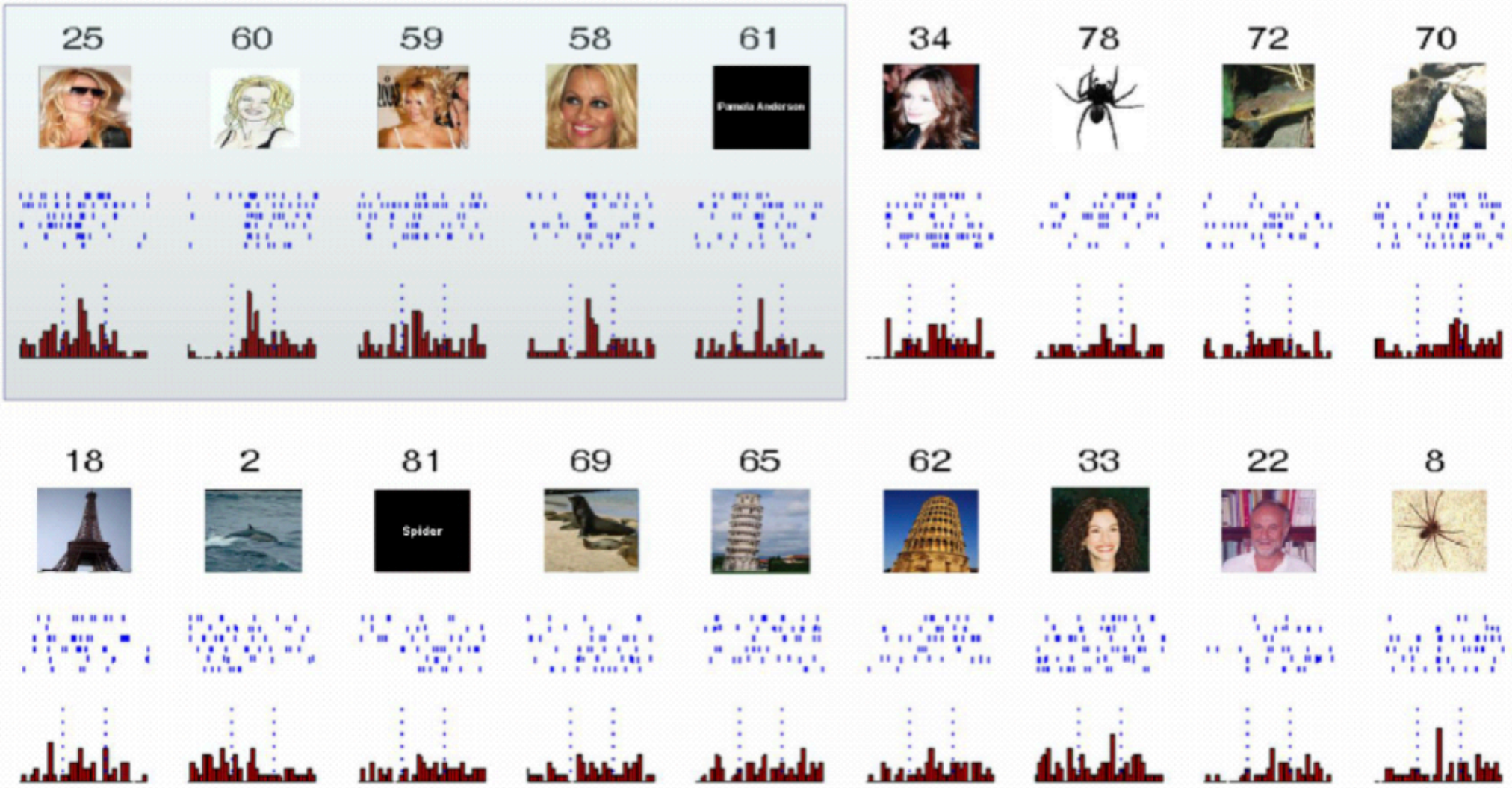
Code 1, continued: Generating and analyzing multiple trials of a spike train

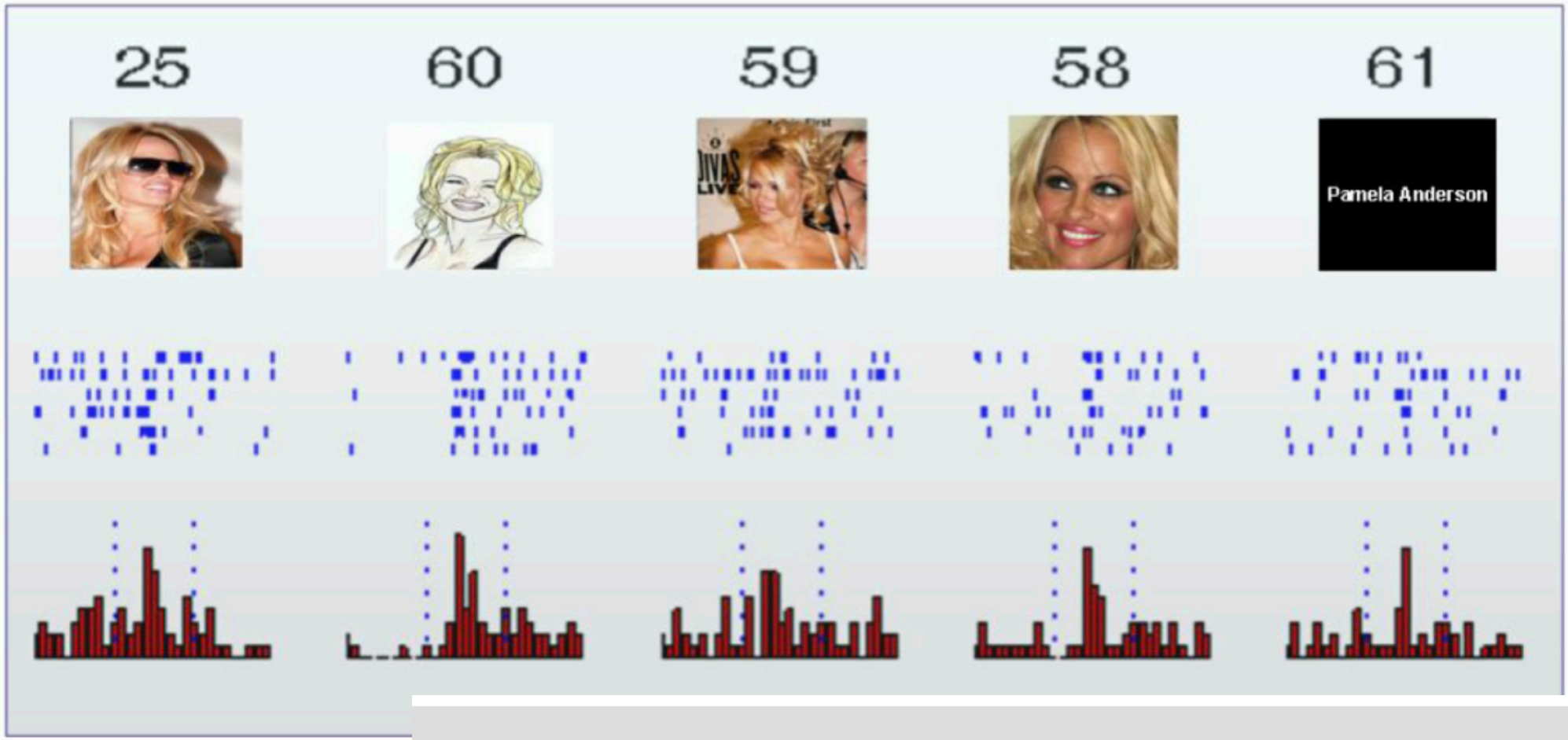
```
%Generate many "trials" of spiketrains
numtrials=10;
spiketrain=round(rand(numtrials,numbins) +
(p-1/2));

figure;
imagesc(spiketrain)
xlabel('time')
ylabel('trial')


%Compute the average spike rate, and standard
deviation
rate_per_trial=1/T * sum(spiketrain,2)
mean_rate_per_trial = mean(rate_per_trial)
std_dev_rate_per_trial = std(rate_per_trial)
```

Hand out HW

Complex feature representation




25
60
59
58
61
Pamela Anderson
34
78
72
70
18
2
81
Spider
69
65
62
33
22
8



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LETTERS

Invariant visual representation by single neurons in the human brain

R. Quian Quiroga[1,2]†, L. Reddy[1], G. Kreiman[3], C. Koch[1] & I. Fried[2,4]