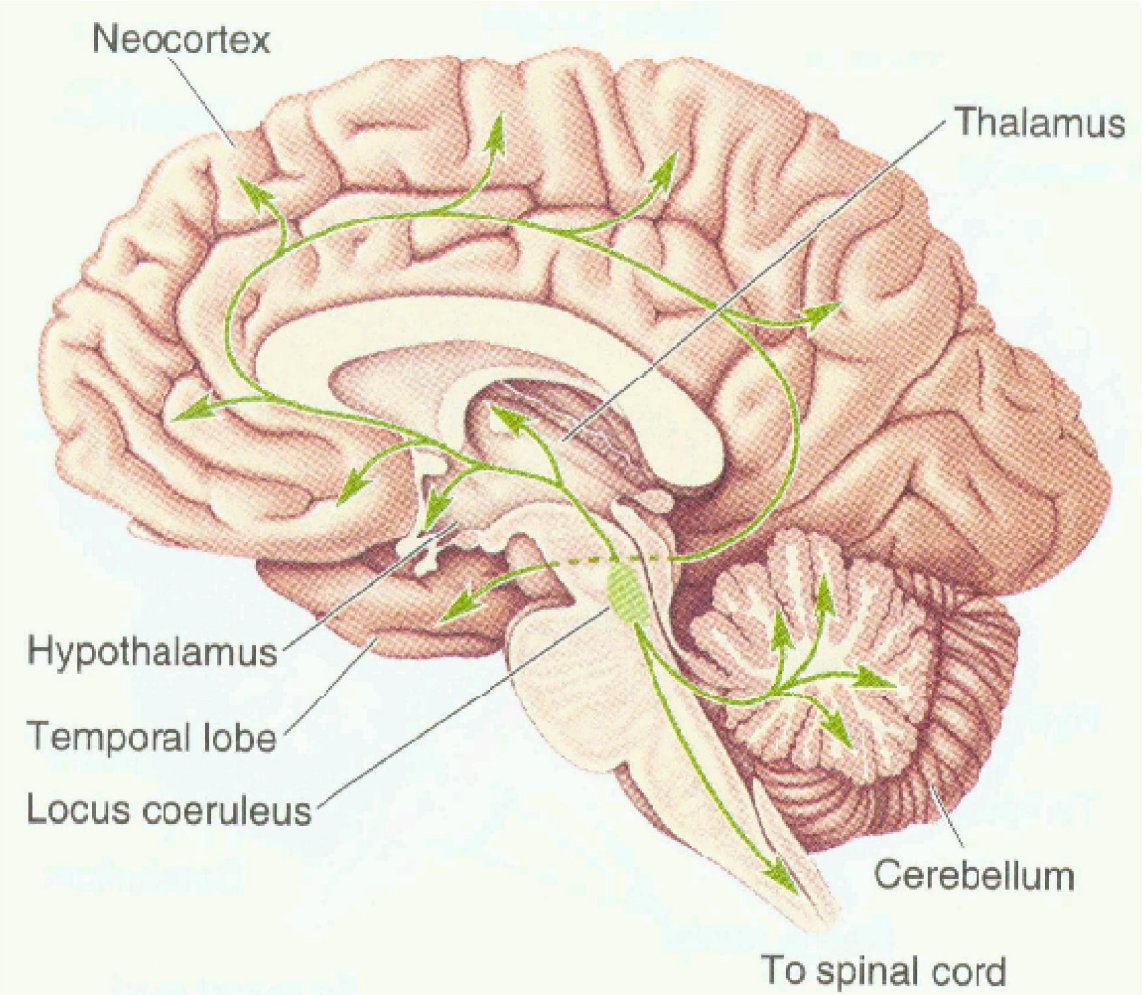


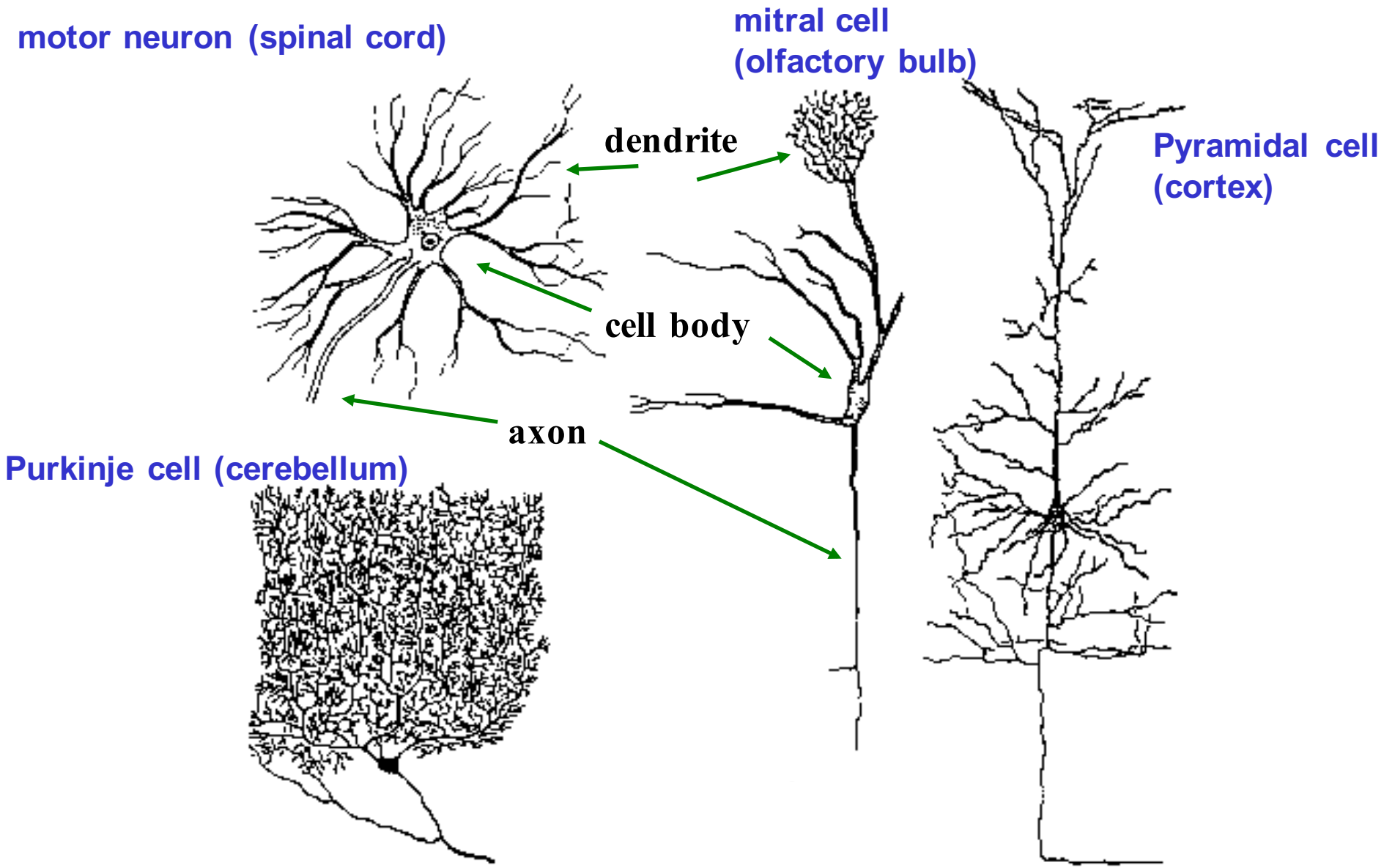
from *Neuroscience: Exploring the Brain* by M.F. Bear, B.W. Connors, and M.A. Paradiso, 2001

10^{11} neurons

(10^5 per mm^3)

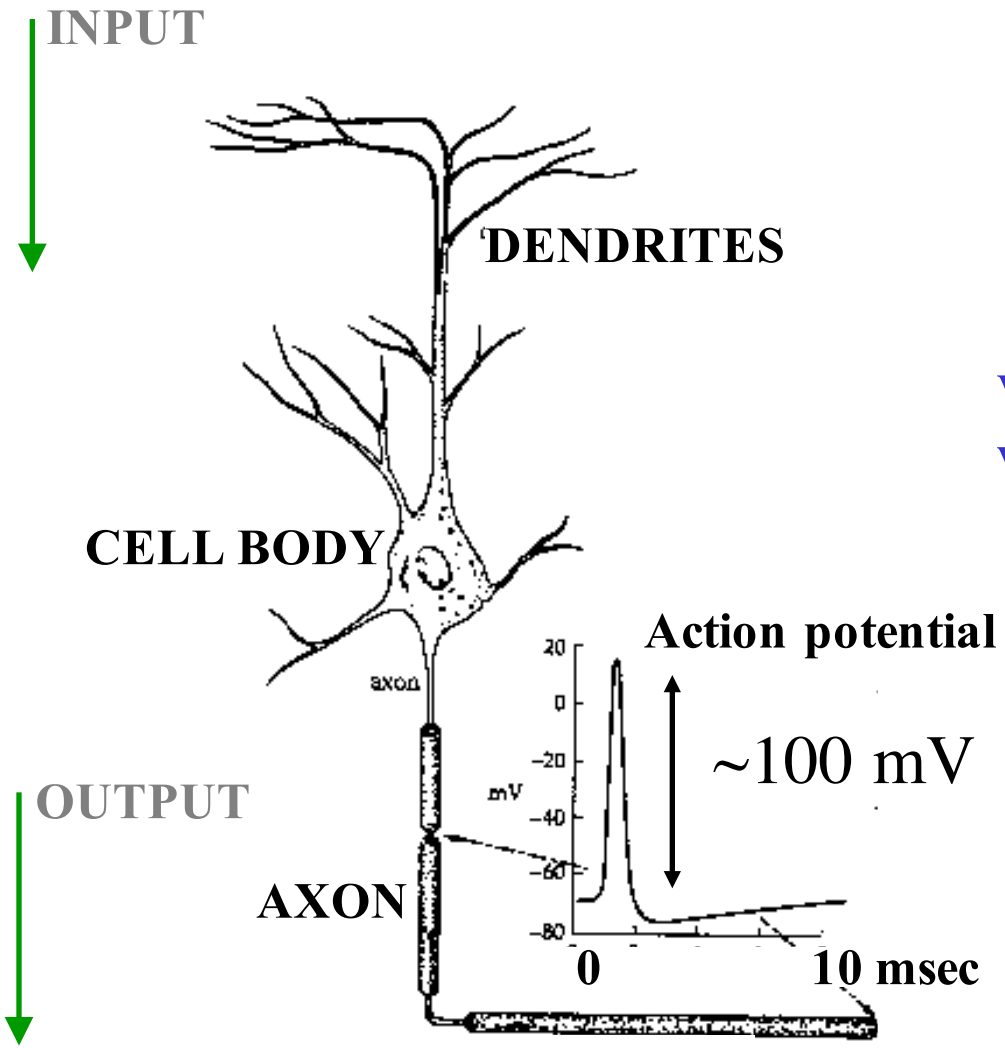
10^{15} synapses

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

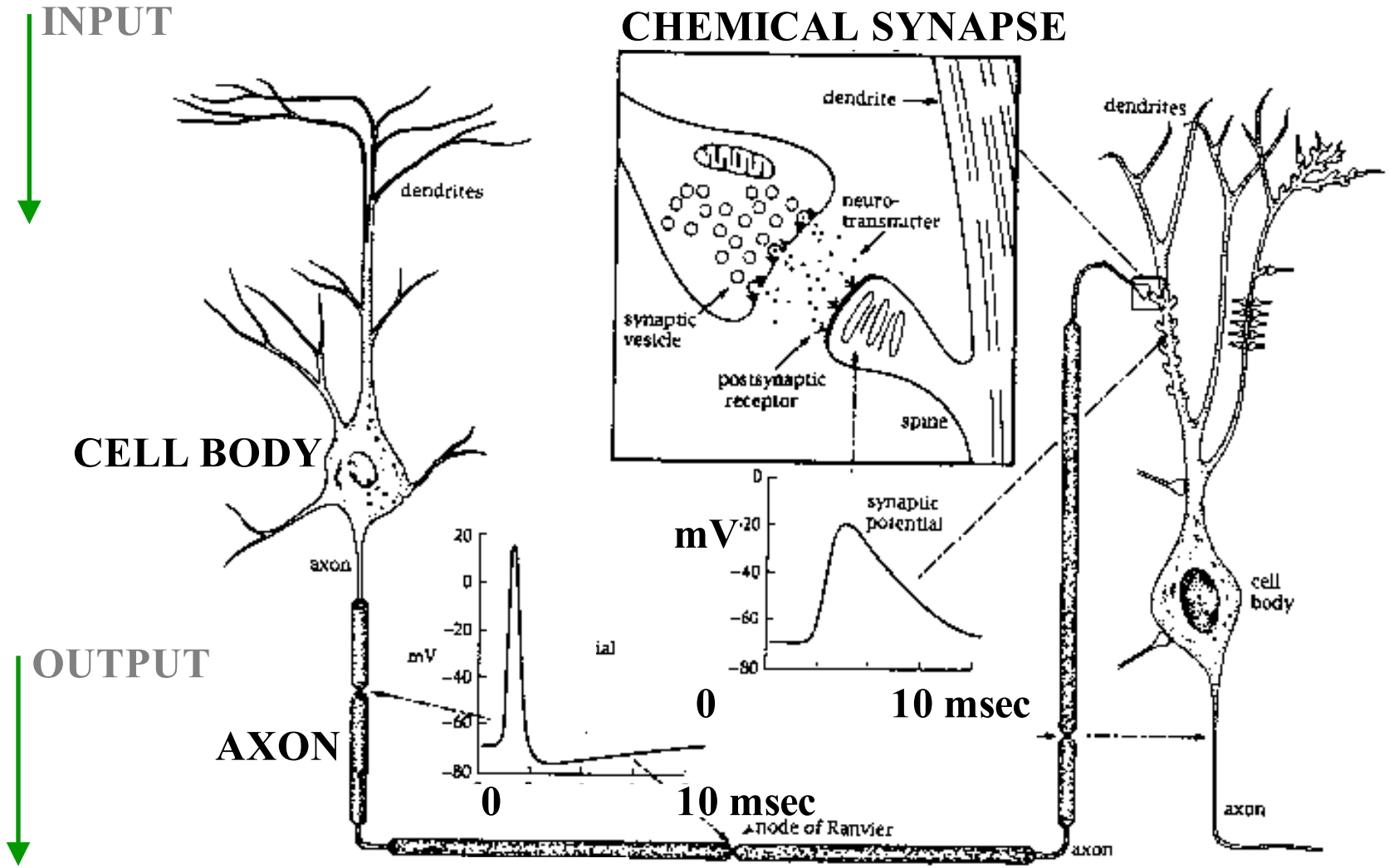


Voltage V: set by "excess charge" inside vs outside membrane (more later)

Johnston and Wu, 1997

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

…which are communicated to downstream neurons via synapses

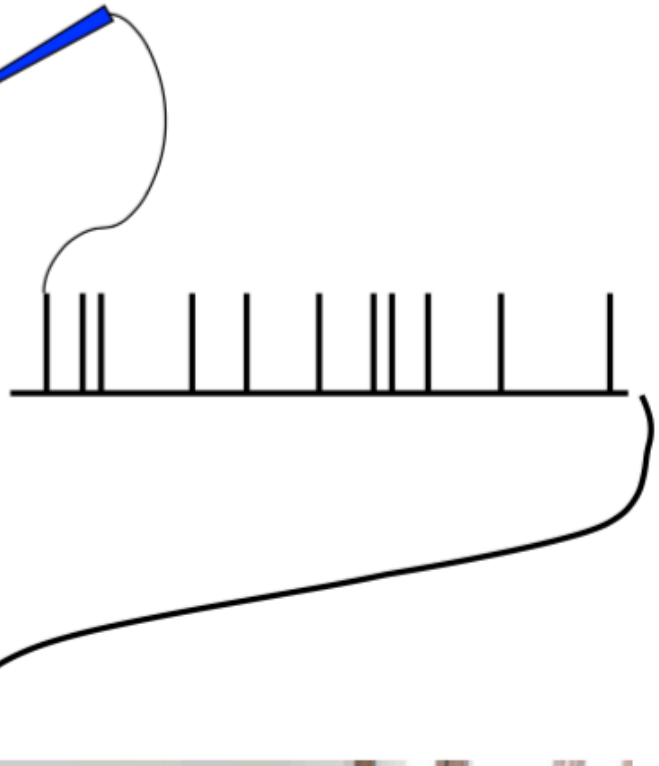


Johnston and Wu, 1997

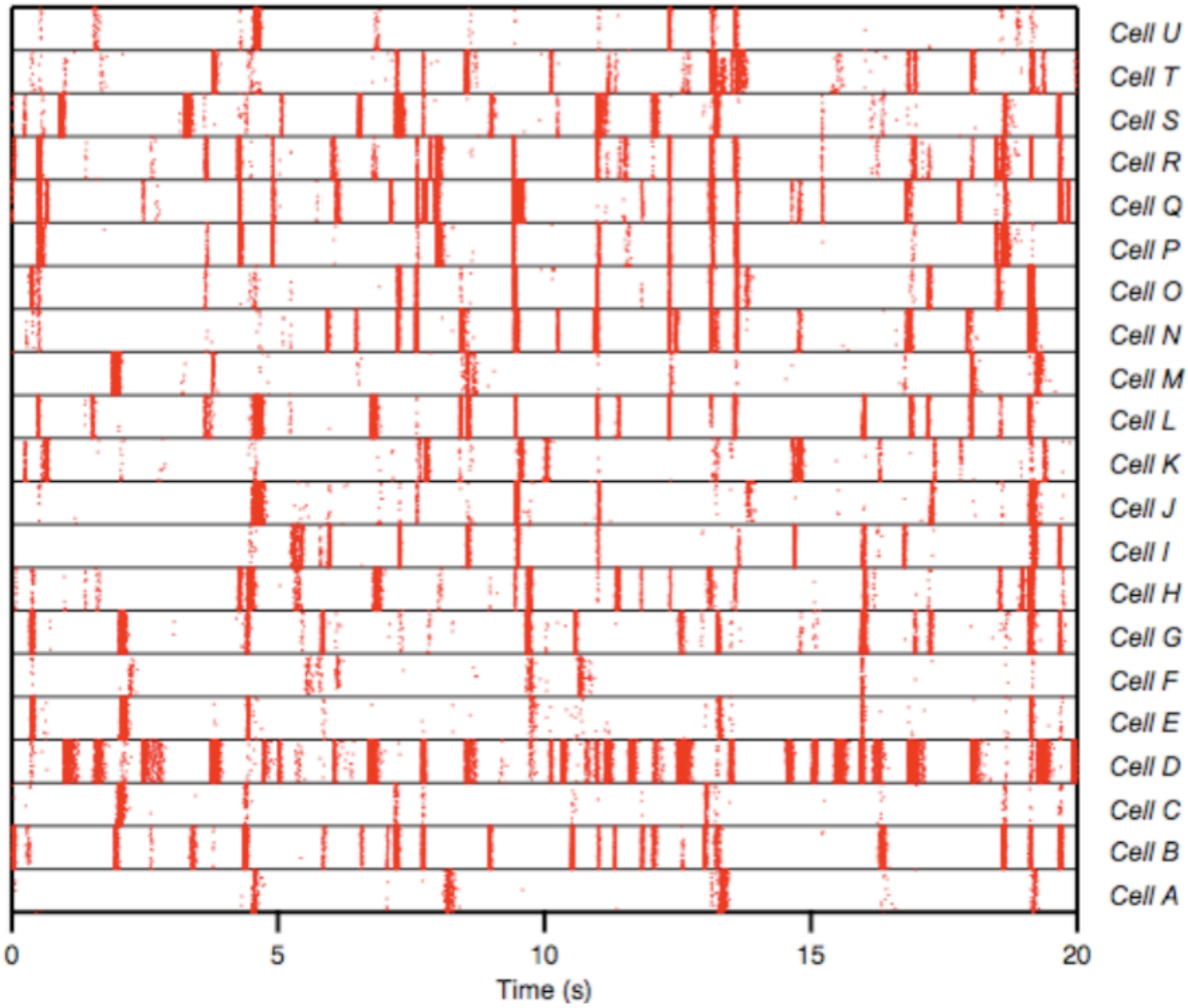
- Overview (blackboard)

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

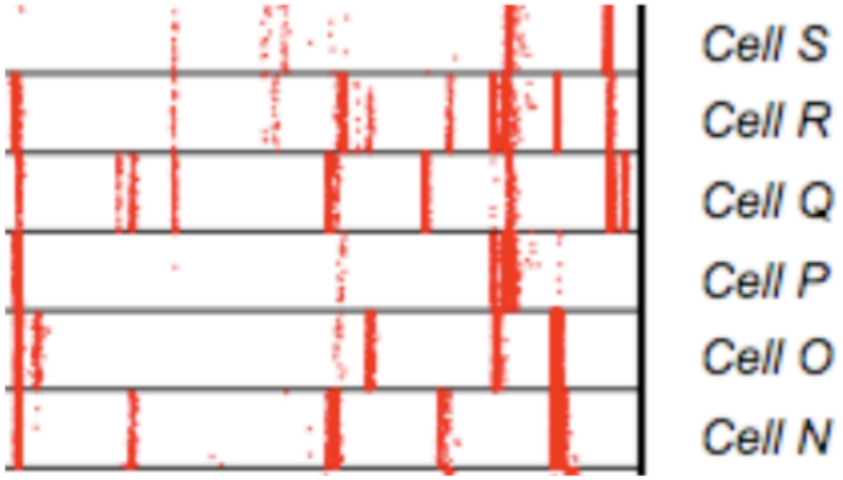
Neural coding



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?

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

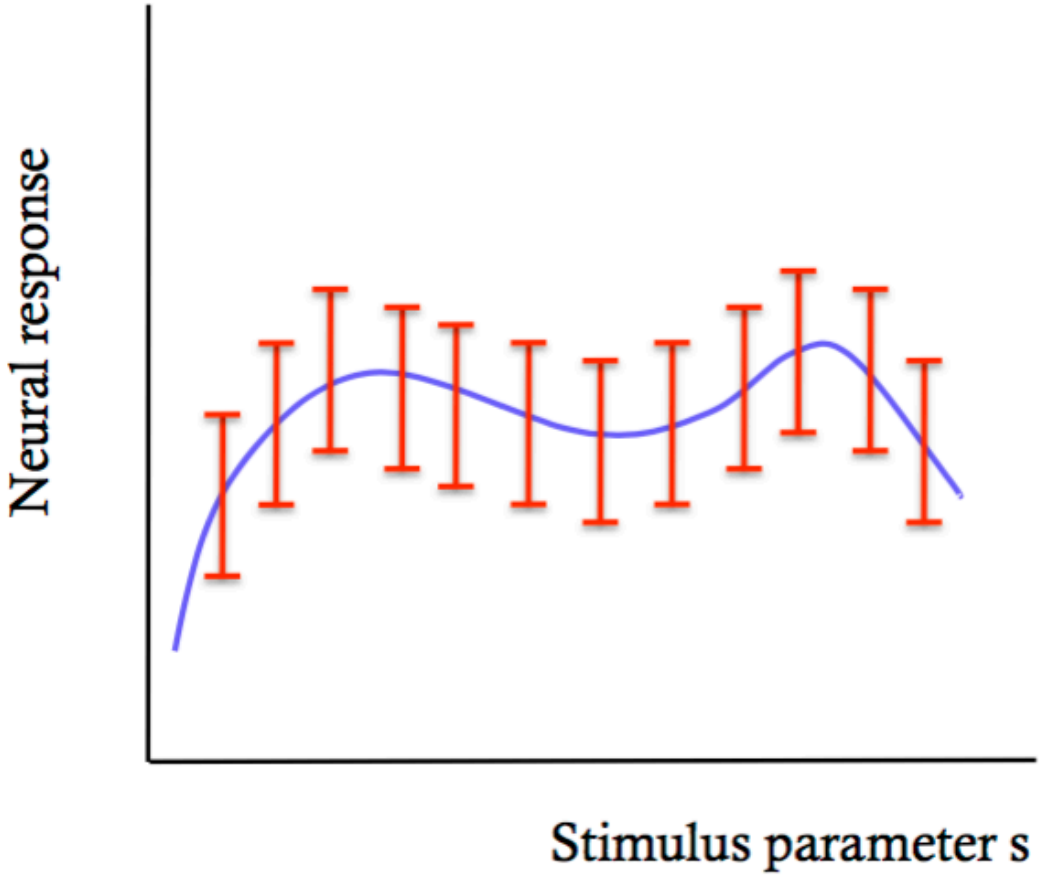
Neural coding

More generally, we are interested in determining the relationship:

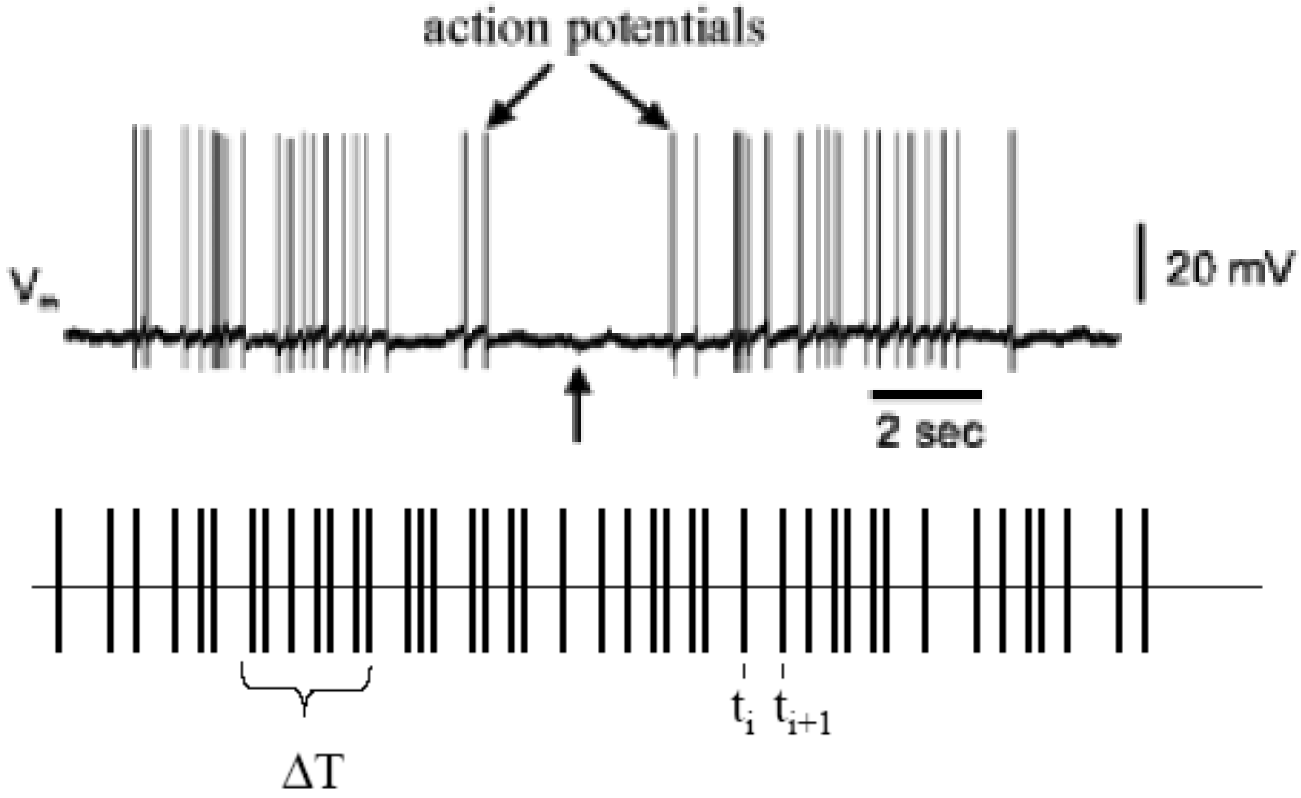
P(response | stimulus) *encoding*

P(stimulus | response) *decoding*

Neuronal representation of information



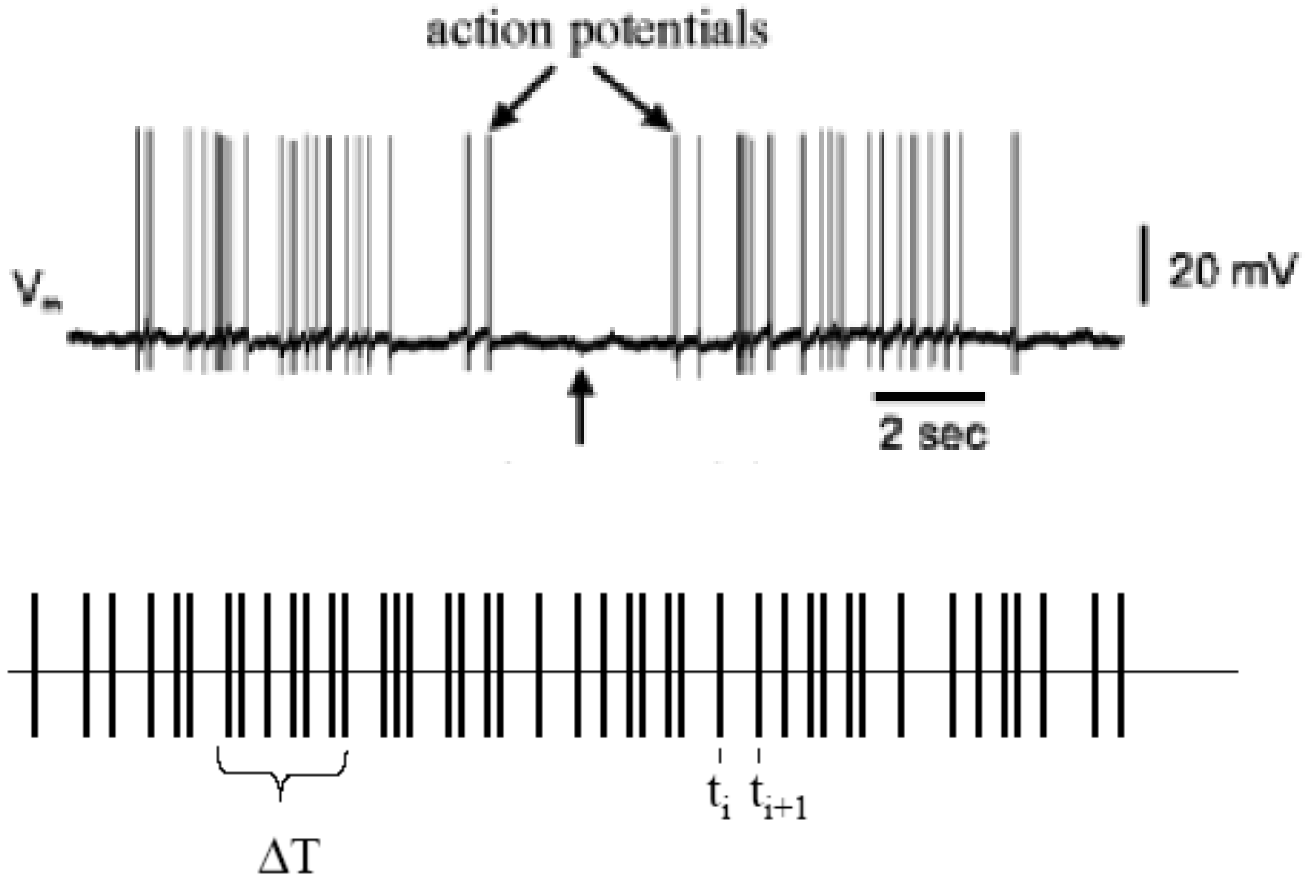
Simplest definition of neural response: *firing rates*



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

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

(Board … definition of delta function)



David Tank

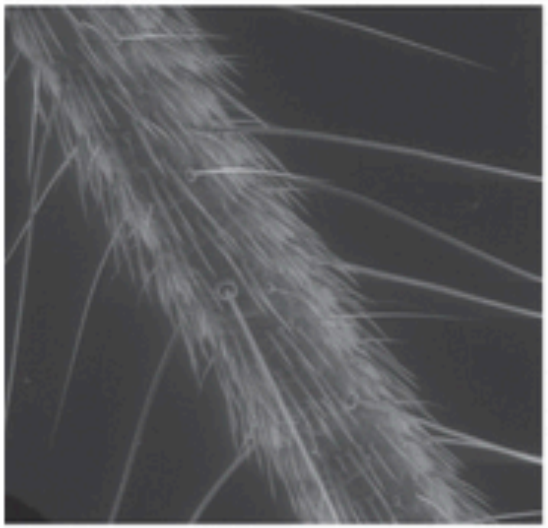
SPIKE TRAIN $$\rho(t) = \sum_{t_i} \delta(t - t_i)$$

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

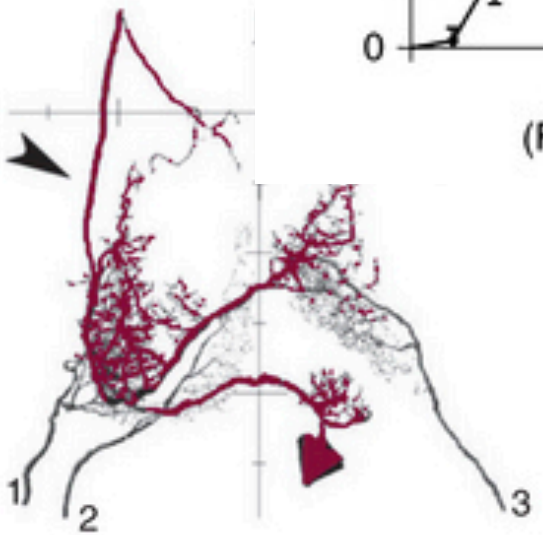
Starting “simple:”
Stimulus ENcoding in the cricket cercal system

Response = firing rate
Stimulus = wind direction

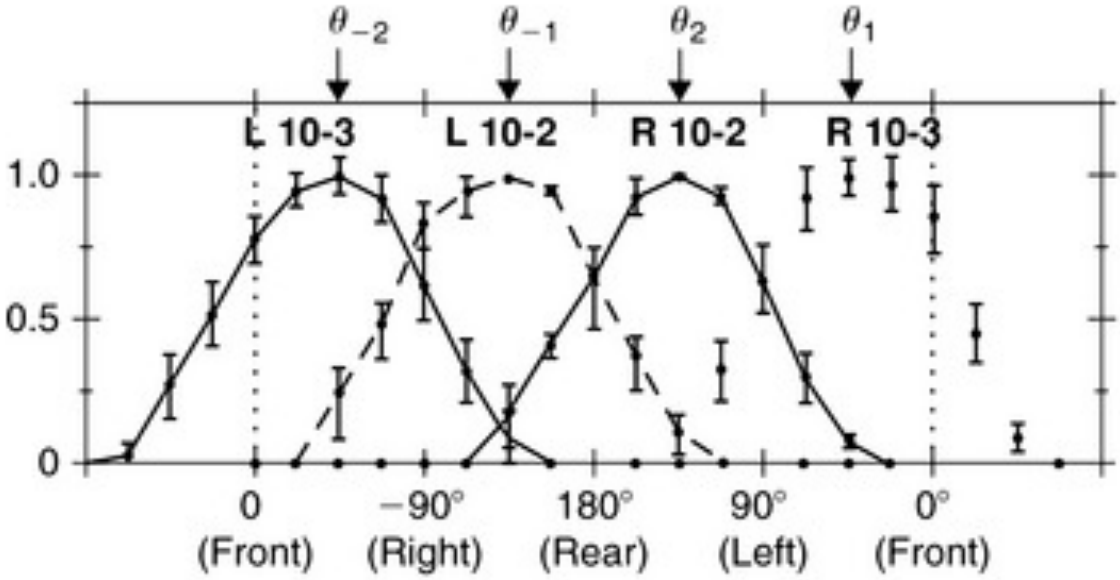
(A)



(B)



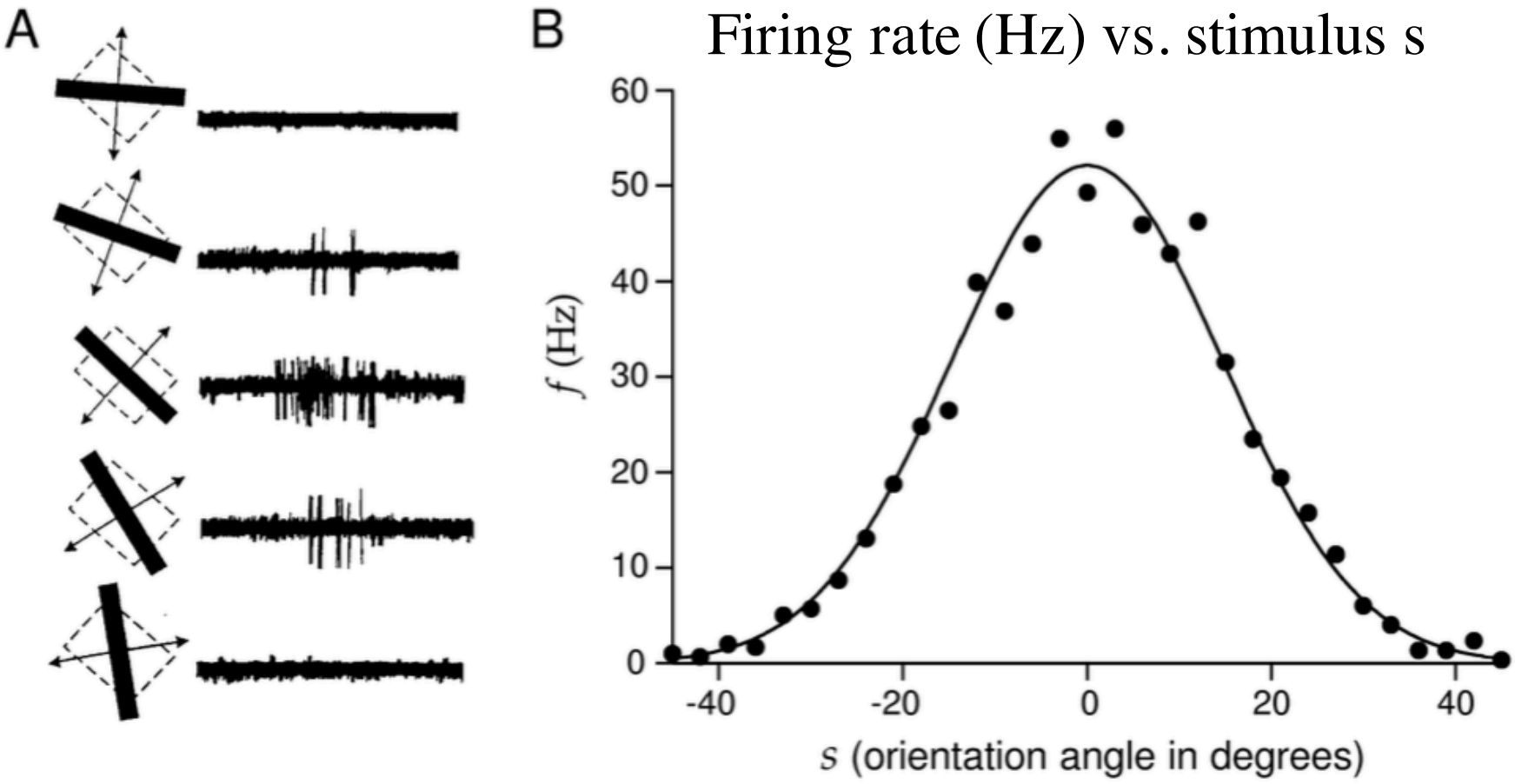
(C)



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)

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)
…
```

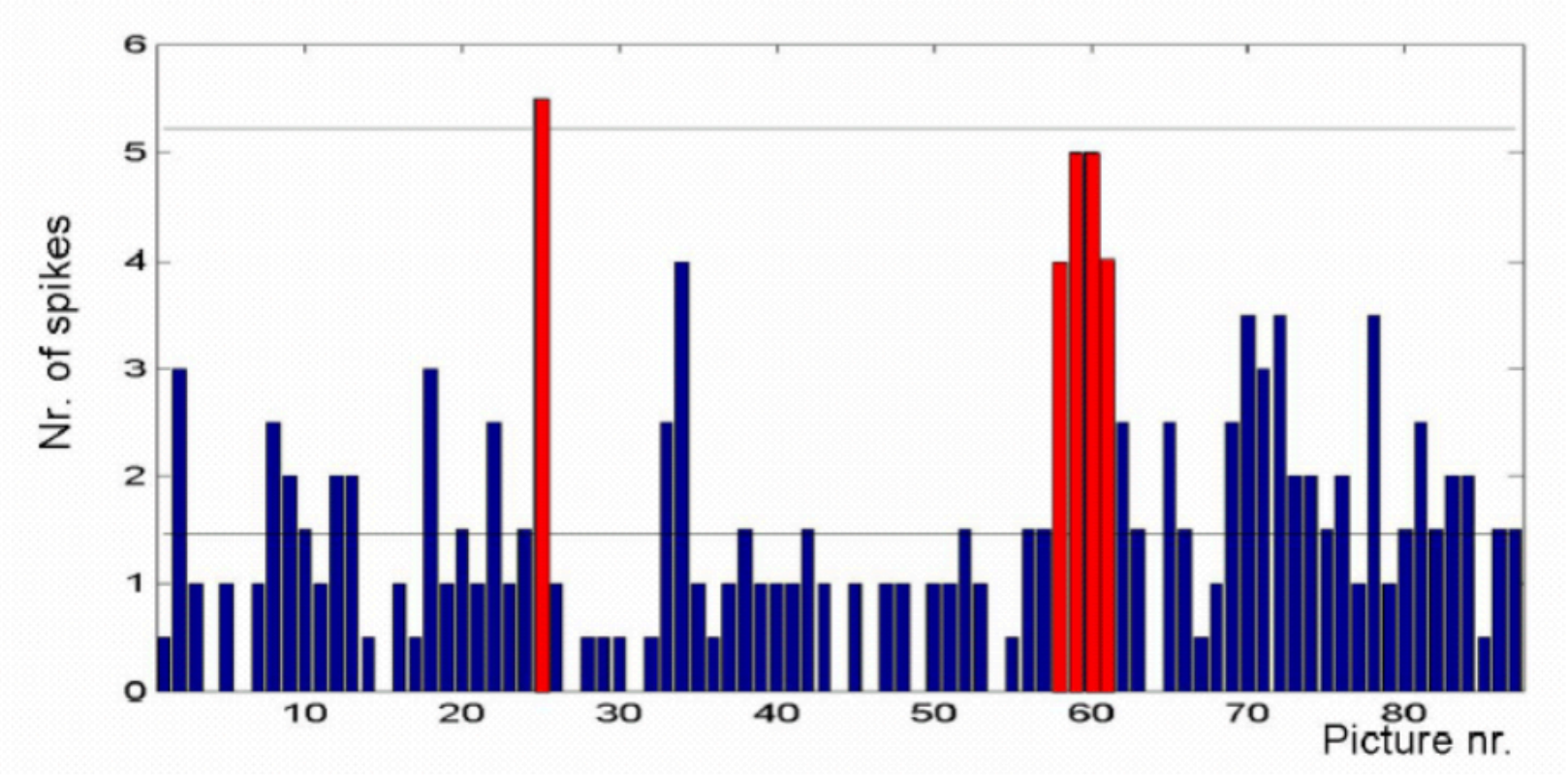
(Board – Mean, variance, std dev)

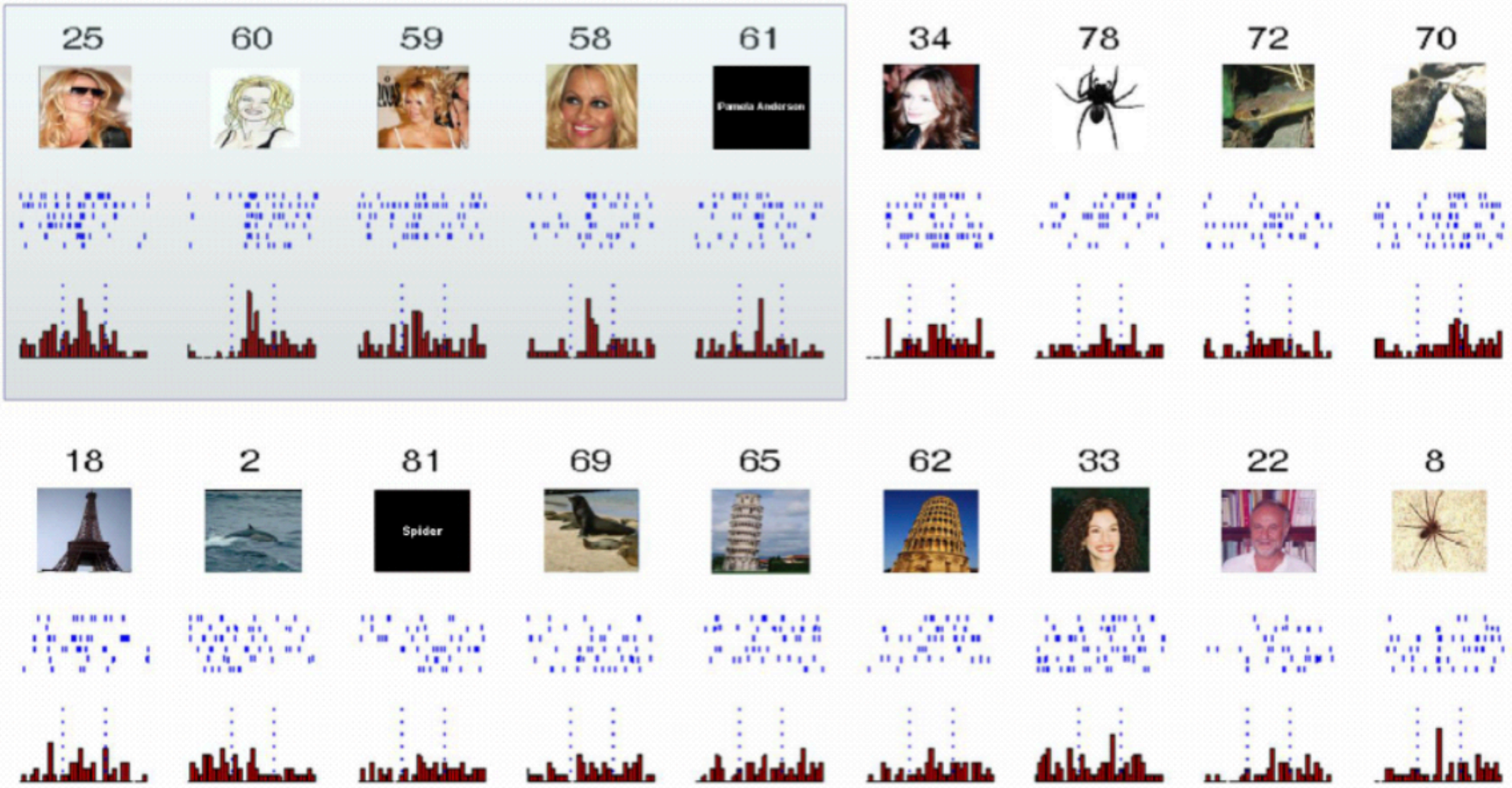
Code 1, continued: Generating and analyzing multiple trials of a spike train

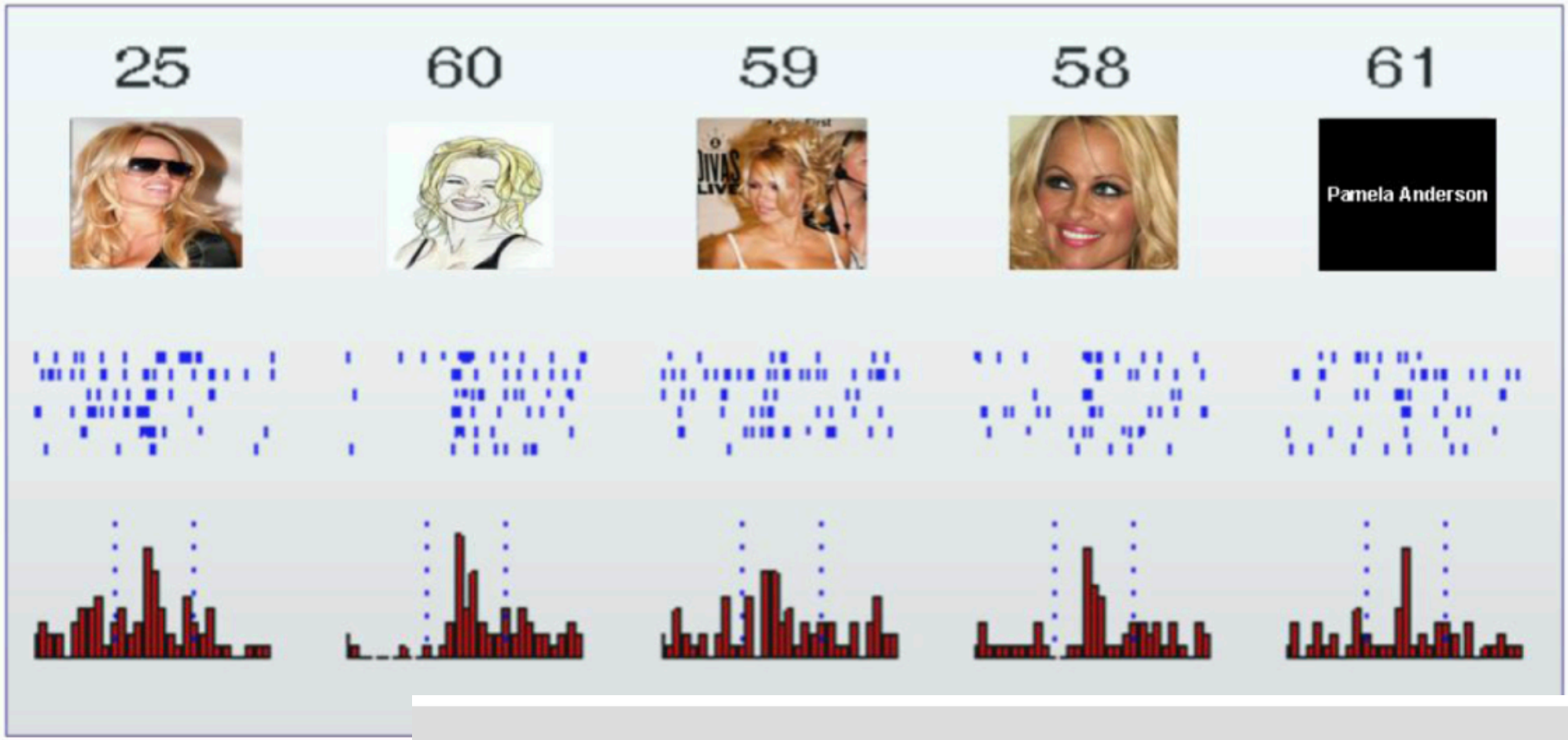
```
%Generate many "trials" of spiketrains
numtrials=10;
spiketrain=round(rand(numtrials,numbins) +
(p-1/2));

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

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