Topics in Brain Computer Interfaces CS295-7

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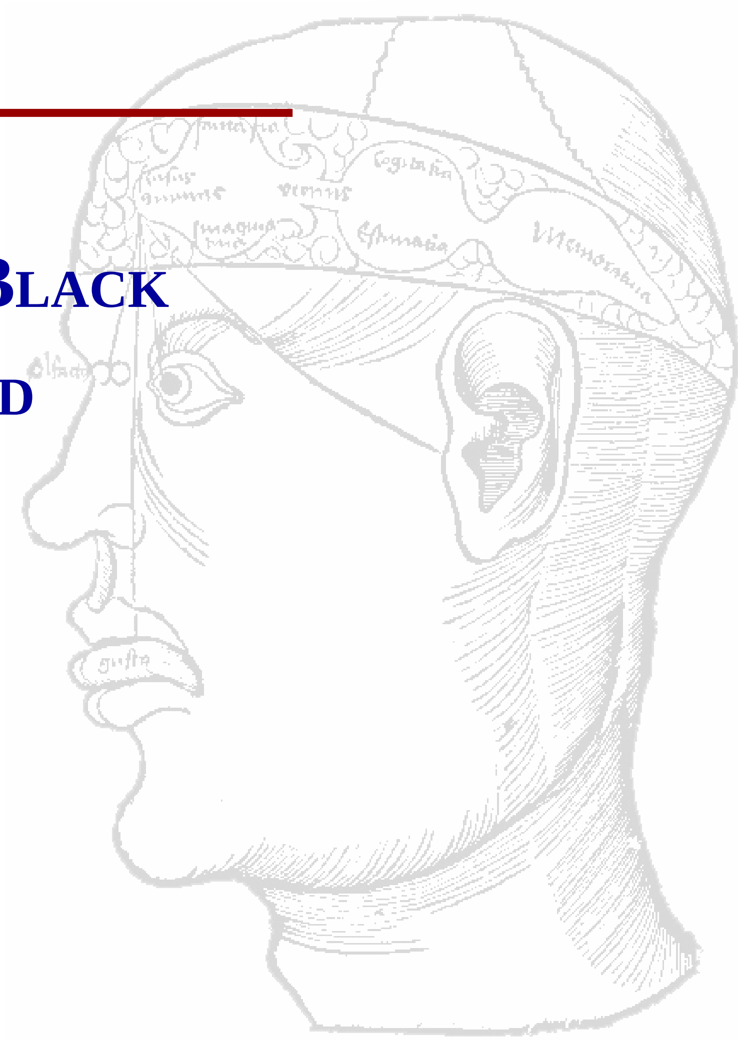
TA: **FRANK WOOD**

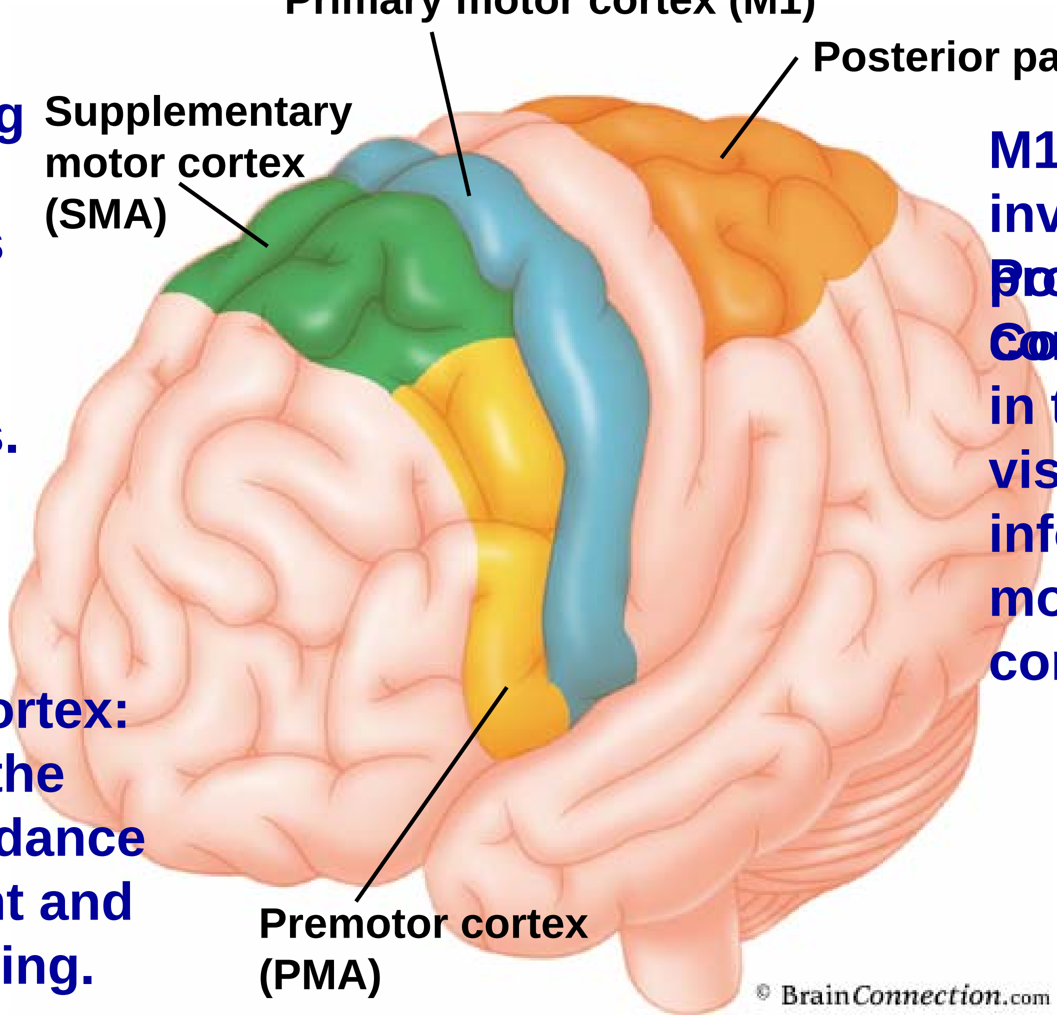
Spring 2005



From what part of the brain should we record?

Motor Systems

SMA: involved in the planning of complex movements and in two-handed movements.

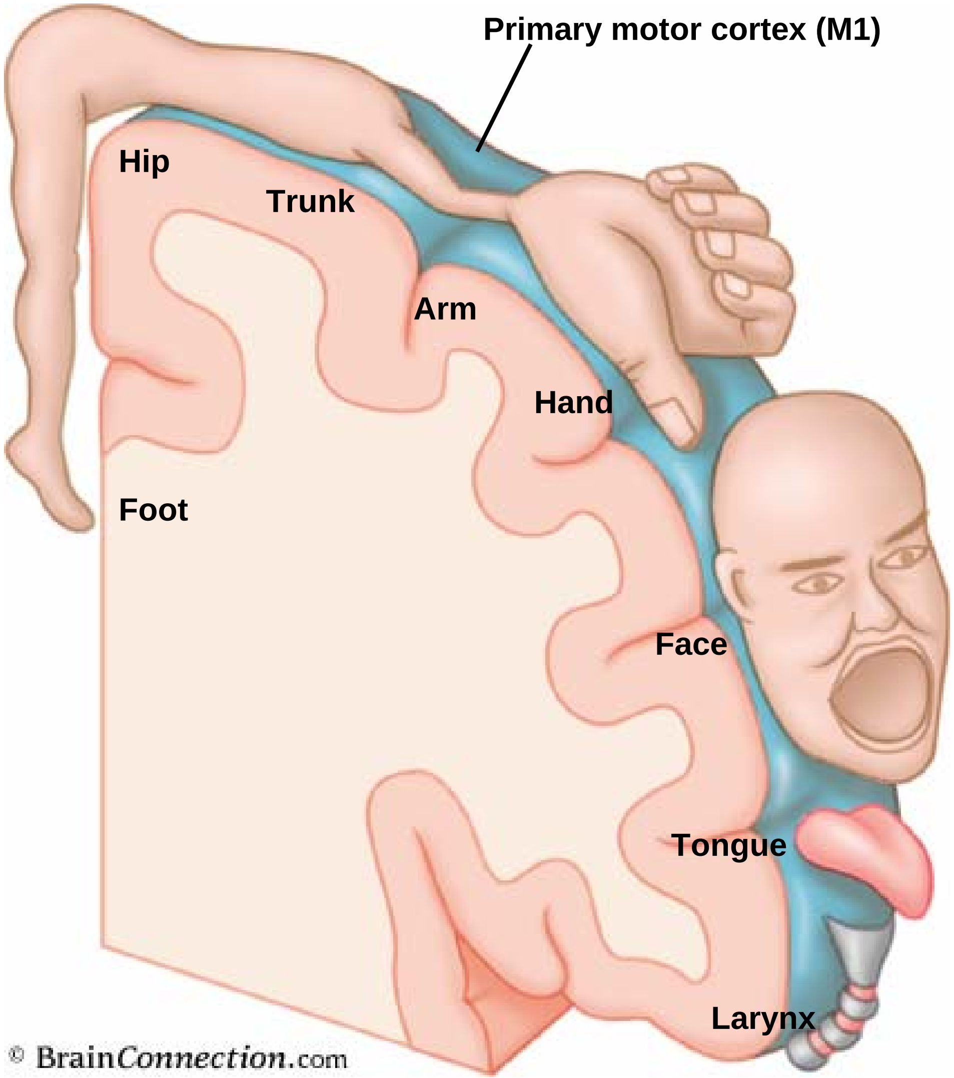


M1: directly involved in producing muscle contraction.

Posterior Parietal Cortex: involved in transforming visual information to motor commands.

Premotor Cortex: involved in the sensory guidance of movement and motor planning.

Motor System

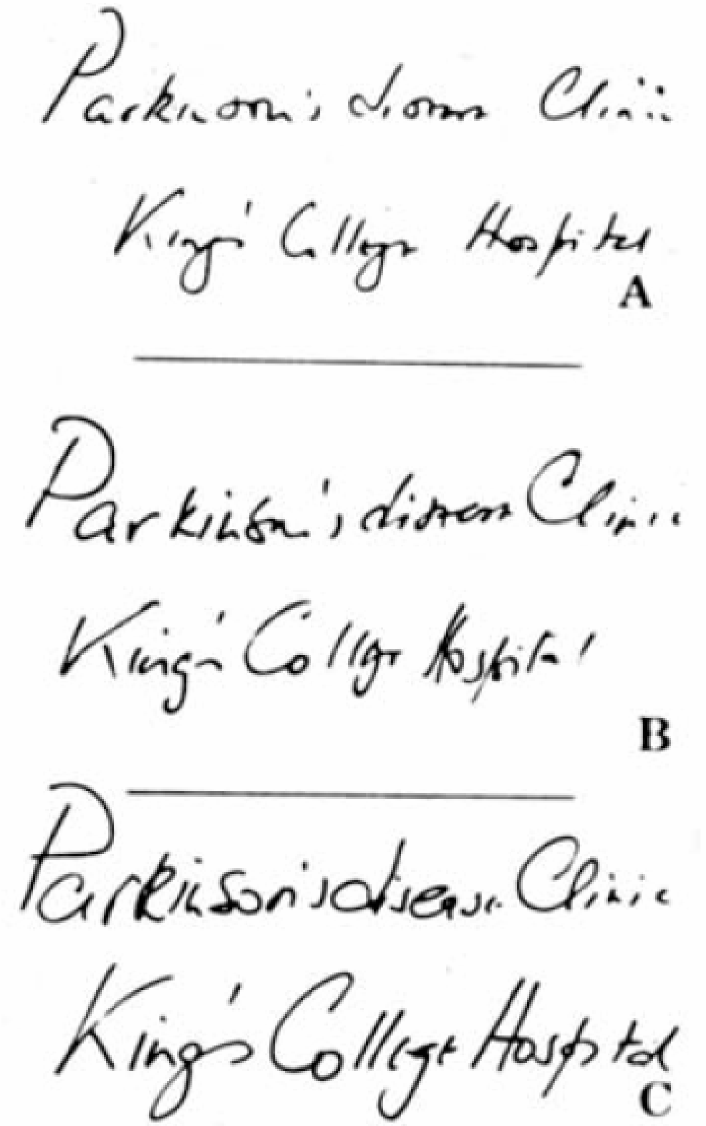


What is represented?

Using wrist and fingers

Using elbow as fulcrum

Using shoulder as fulcrum (outstretched arm)



Adapted from R. Shadmehr

Signing Your Name

Prefrontal Cortex: I'll sign my name.

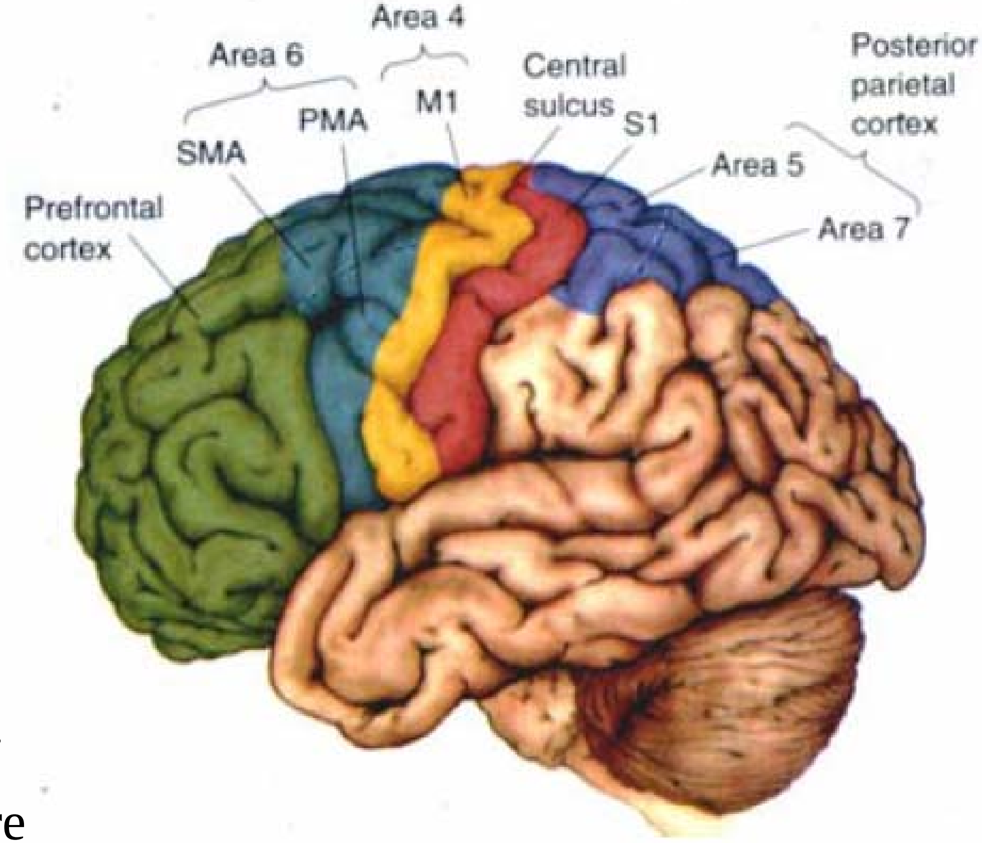
Posterior Parietal: combine visual and somatosensory information to localize pen wrt body.

Premotor cortex: plan motion of hand wrt target path.

Cerebellum: formulate details of movement in terms of dynamics.

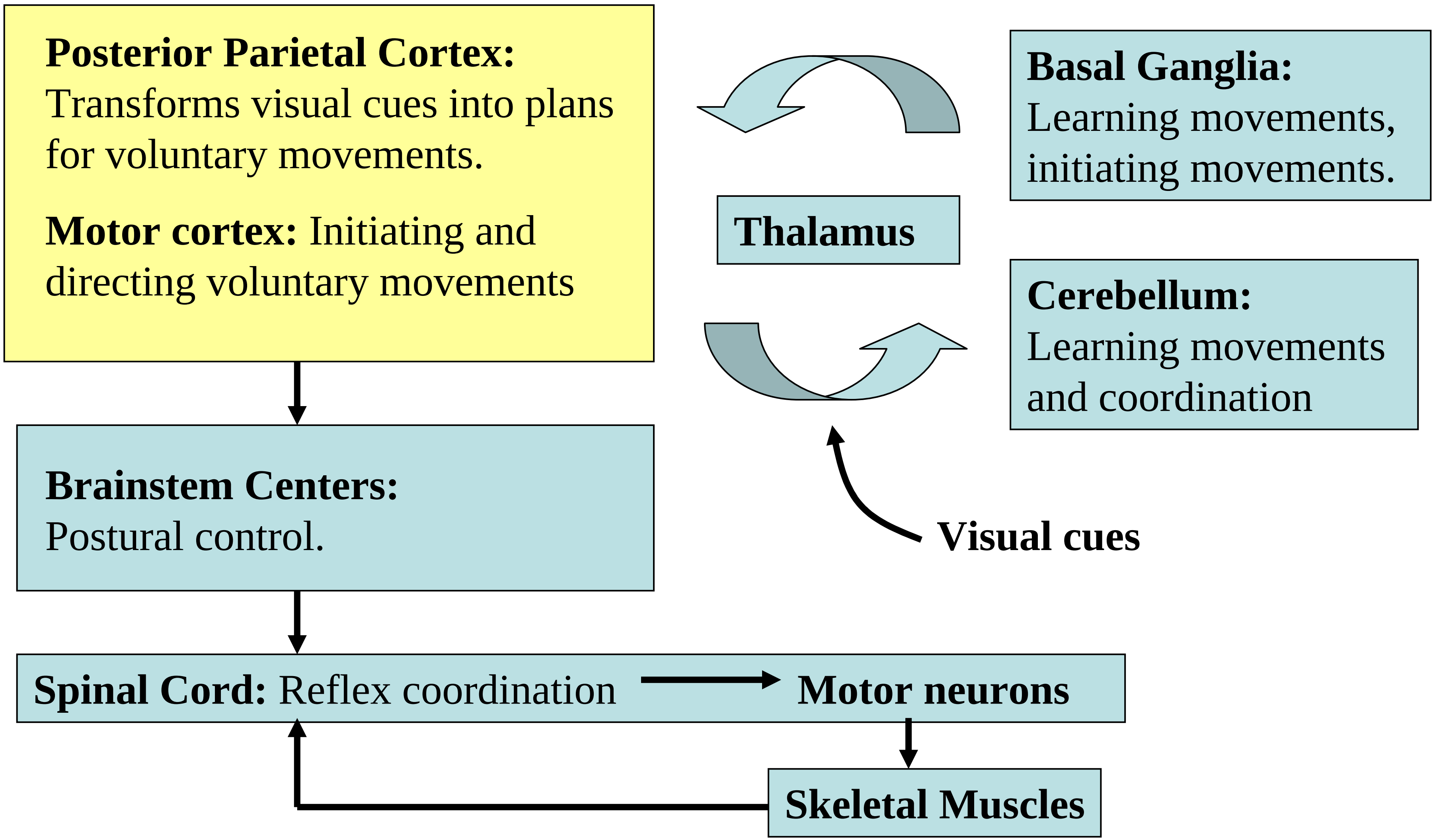
Primary Motor Cortex: sends motor commands down spinal cord.

Brain Stem maintains stable posture during writing.



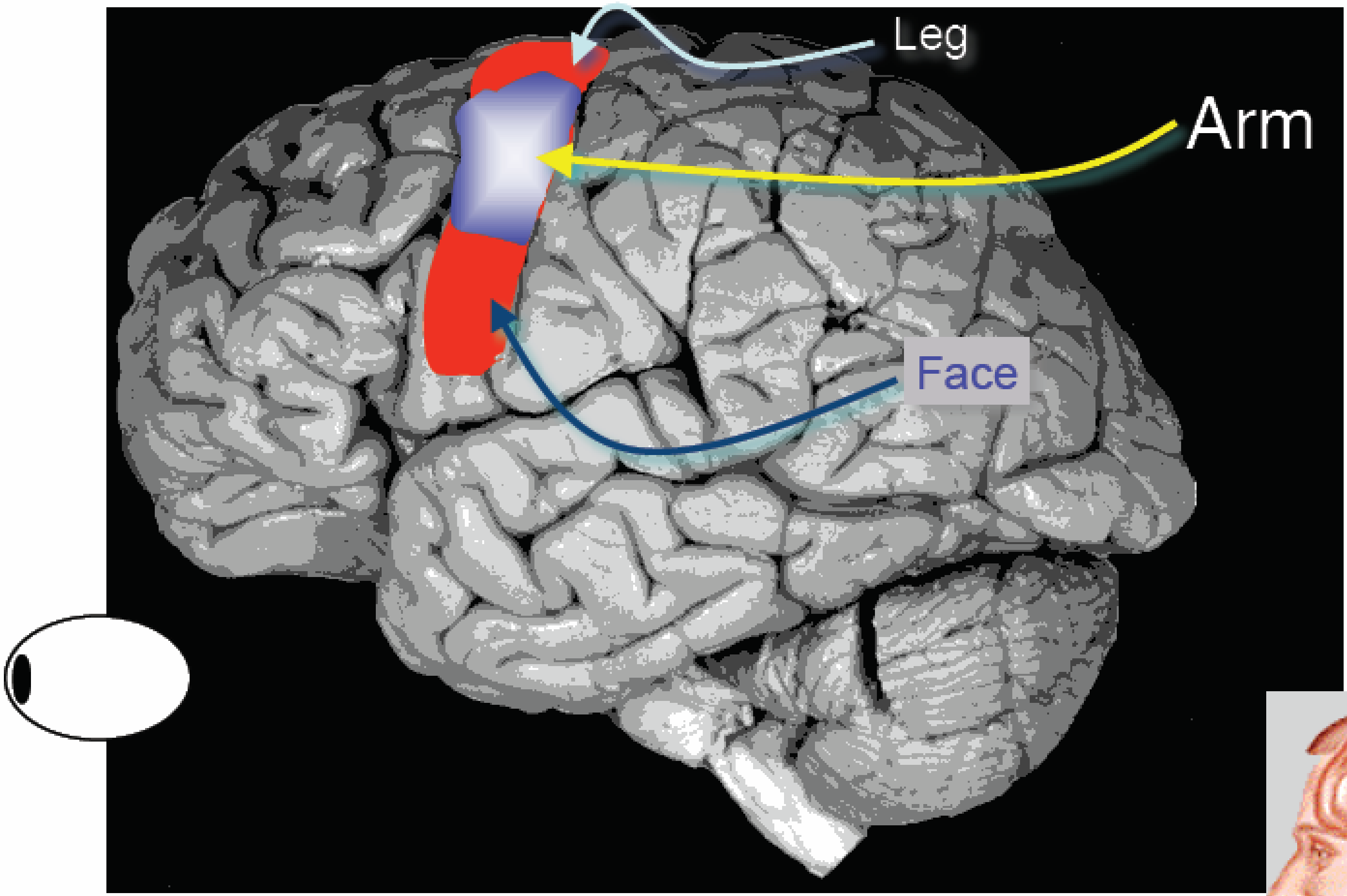
Purves D. et al. (1997)

Summary



Posterior Parietal Cortex: Transforms visual cues into plans for voluntary movements.
Motor cortex: Initiating and directing voluntary movements
Basal Ganglia: Learning movements, initiating movements.
Thalamus
Cerebellum: Learning movements and coordination
Brainstem Centers: Postural control.
Visual cues
Spinal Cord: Reflex coordination
Motor neurons
Skeletal Muscles

Motor Control



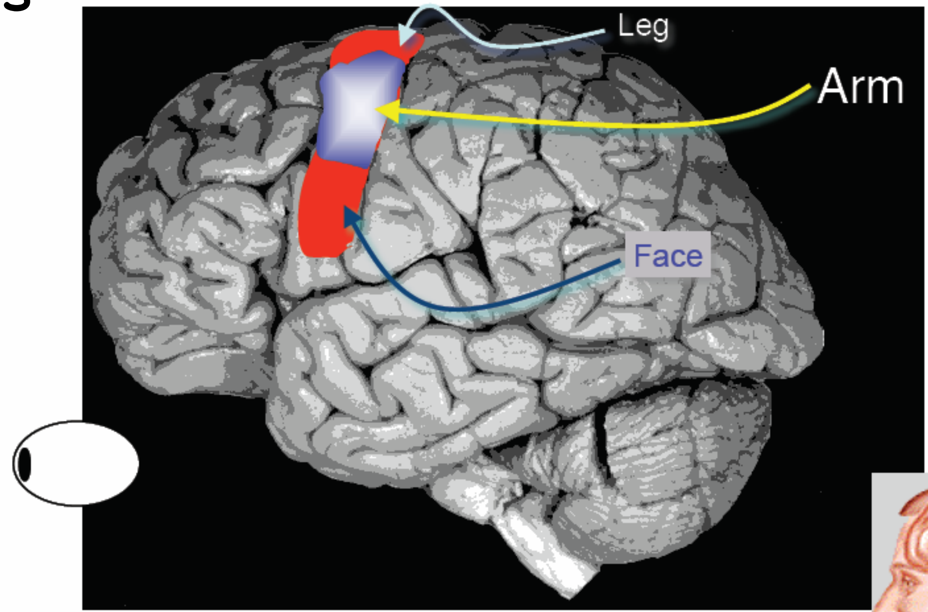
Controlling a Motor Prosthesis

MI arm area of motor cortex.

* know that activity of cells related to hand motion

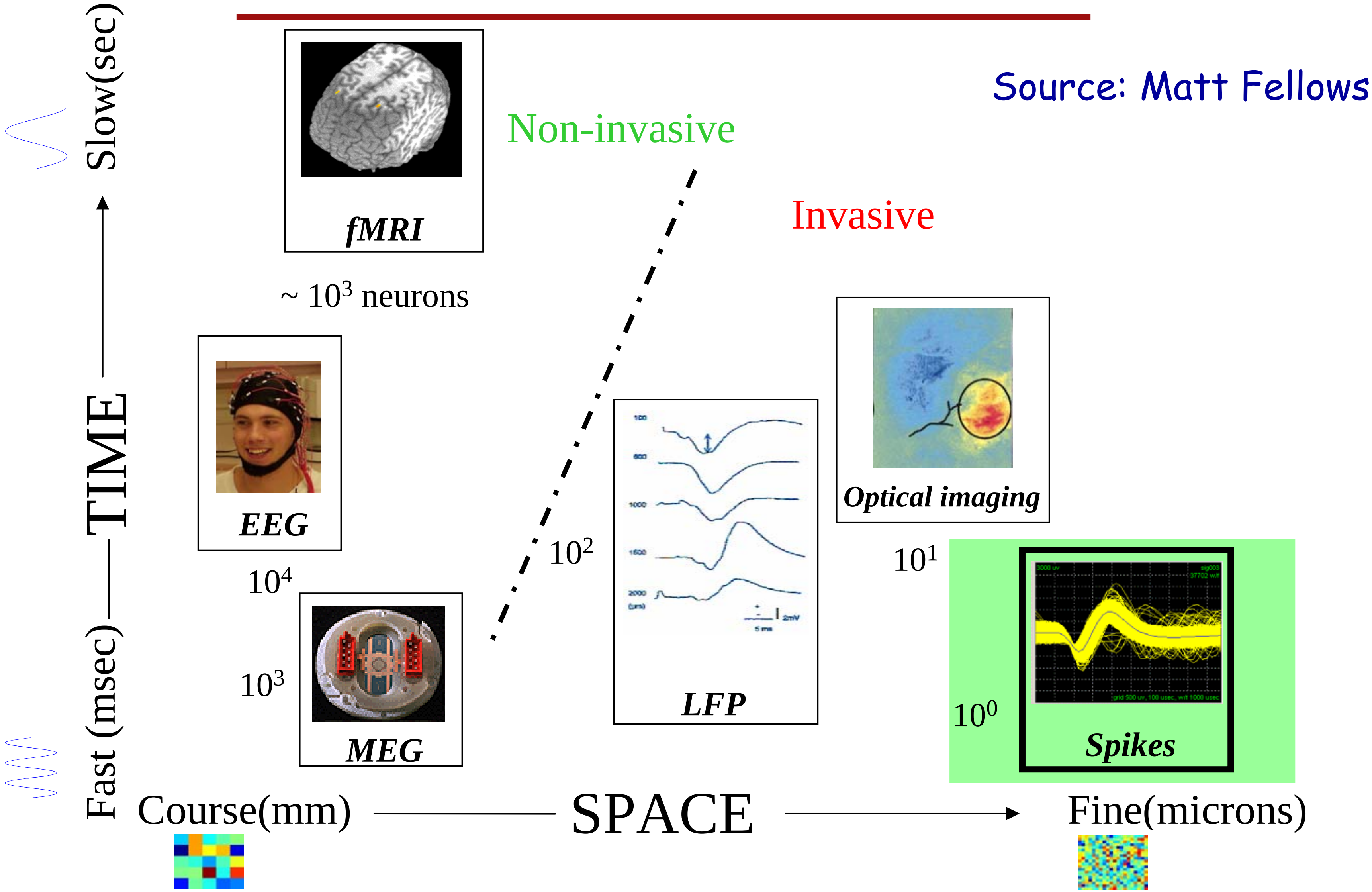
* accessible (in monkeys and humans)

* *hypothesis:* natural for controlling continuous motion of a prosthesis

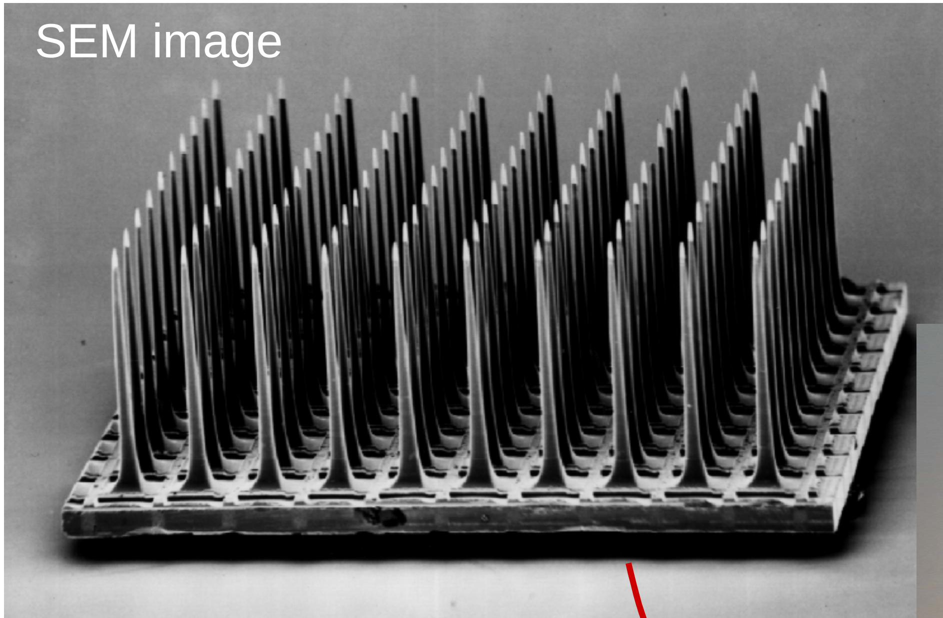


How can we **record** the neural signals?

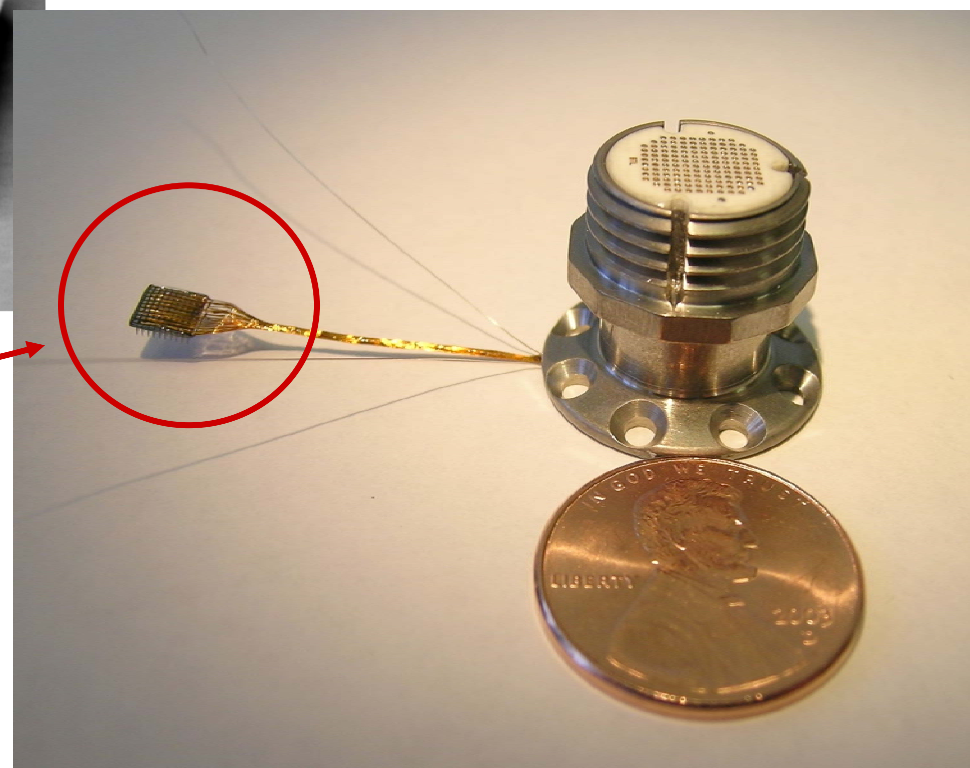
Sensing the Brain



Cyberkinetics Array



Extra-cellular recording



100 “ideal” microelectrodes
10x10 grid,
4x4 mm platform
1 or 1.5 mm long, Si shafts,
Pt coated tips
Glass separation
Parylene insulation coating

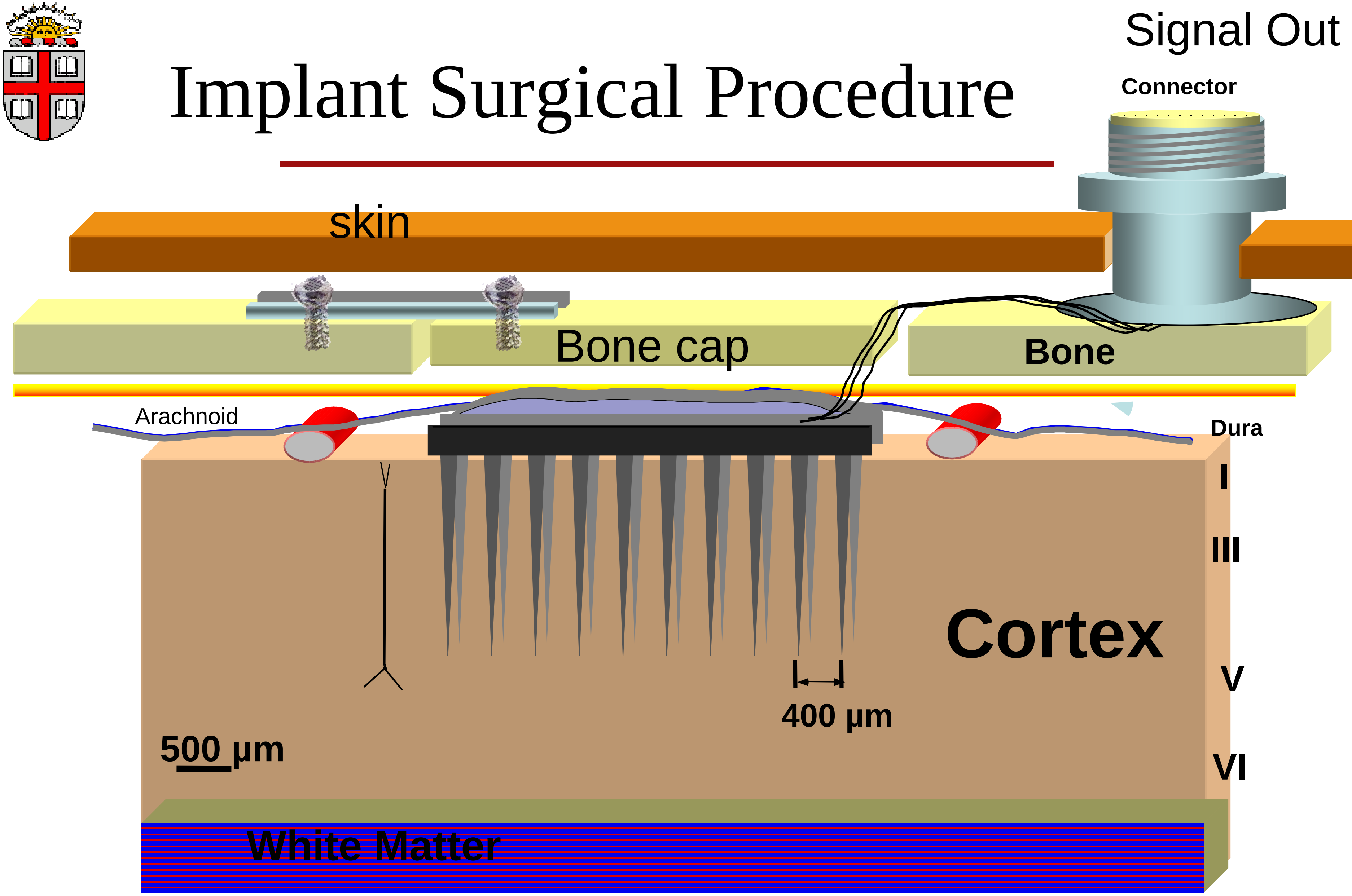
Array

Utah = Bionic = Cyberkinetics array.

Fixed electrode depths – can't move them to get a better signal. Take what you get and make the most of it.

Inventor: Richard Normann, Univ. of Utah.

Implant Surgical Procedure



J. Donoghue 1/2001

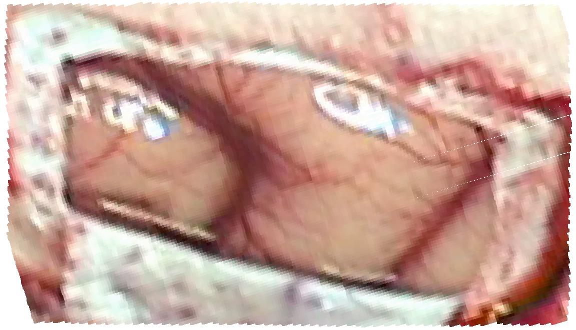
Surgical Implantation

WARNING:

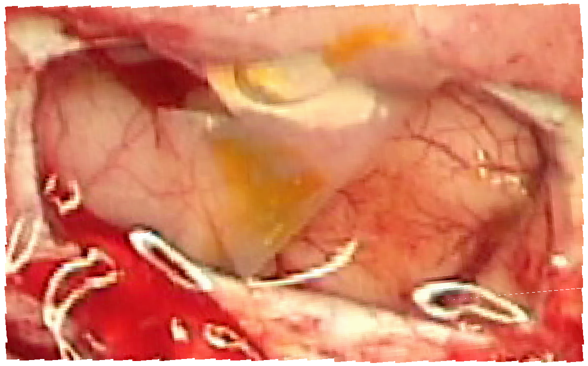
Graphic images of surgical procedure follow.

Preclinical Safety:
Removal and Re-implantation

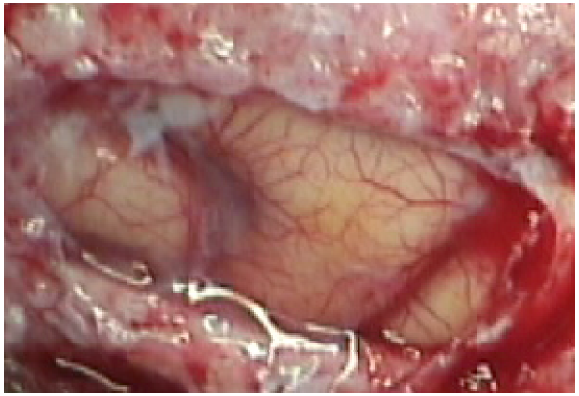
First Implant | Explant | Second Implant



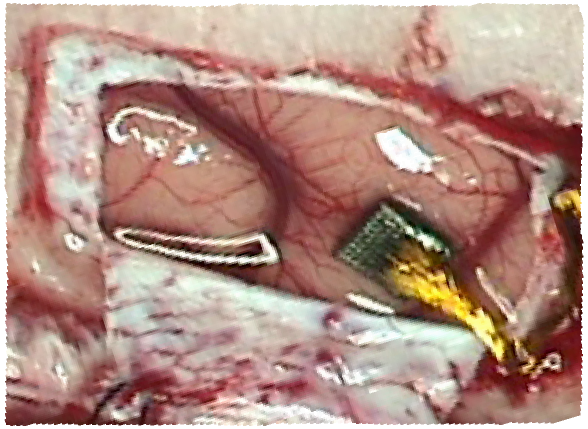
F1 Original Implant

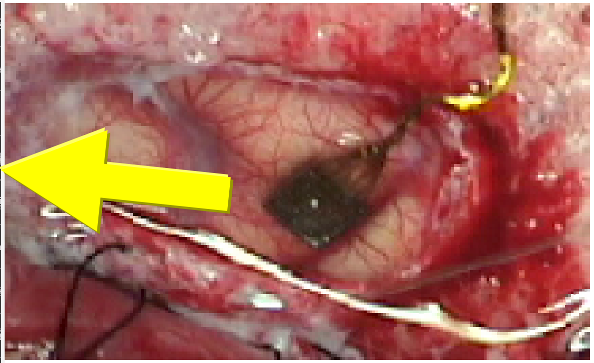


F2 + 4 wks Removed



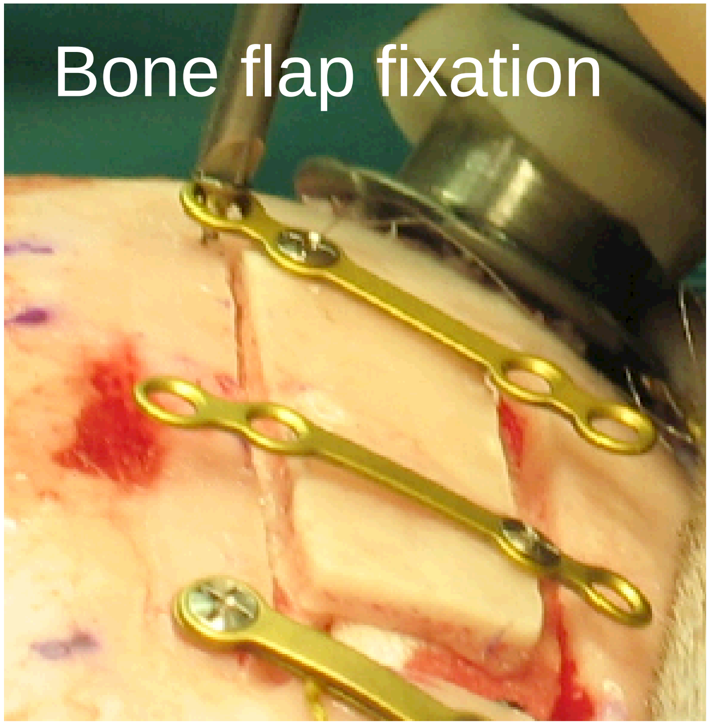
F3 +3 months





Donoghue Lab

Surgical Methods

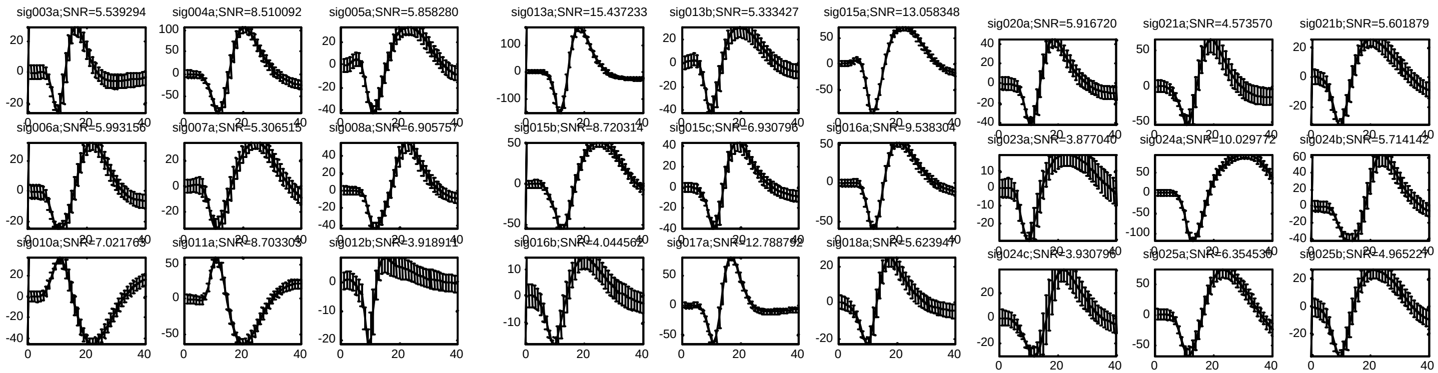


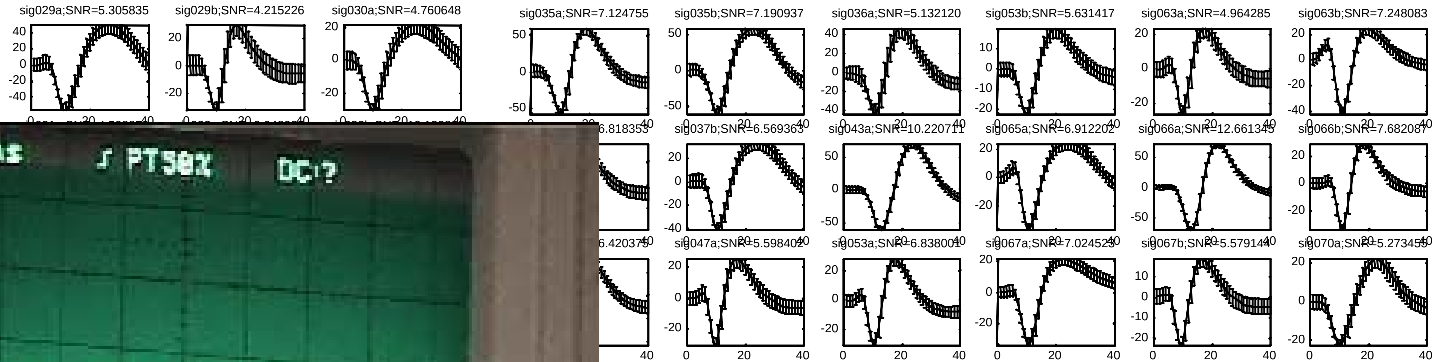
Skin closure

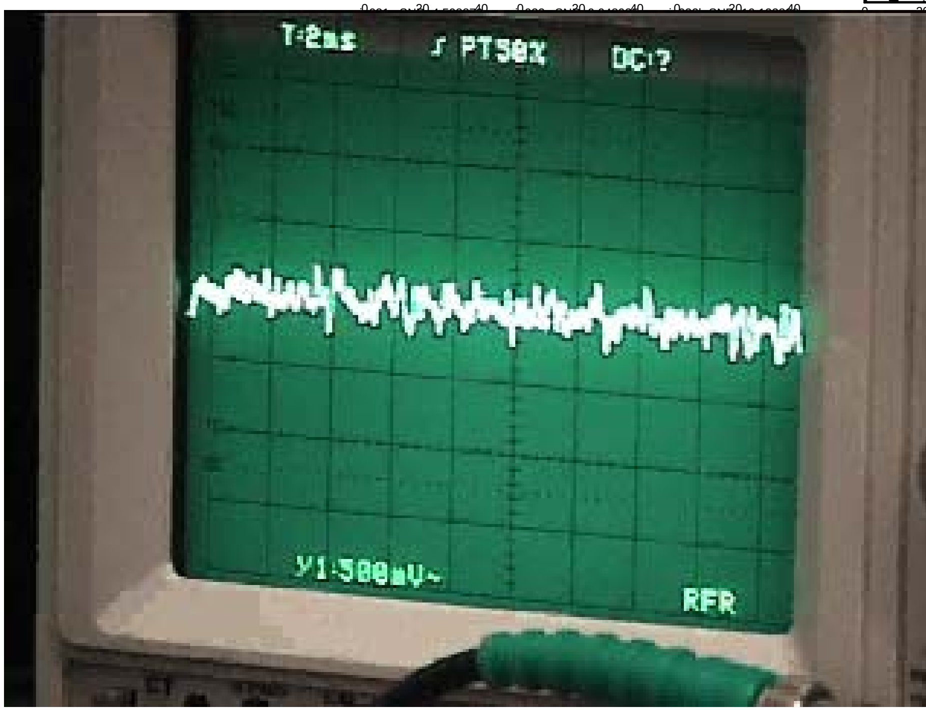
Percutaneous Connector

Intended to follow human neurosurgical procedures and methods.

- Limit duration
- Eliminate most foreign materials
- use established surgical methods



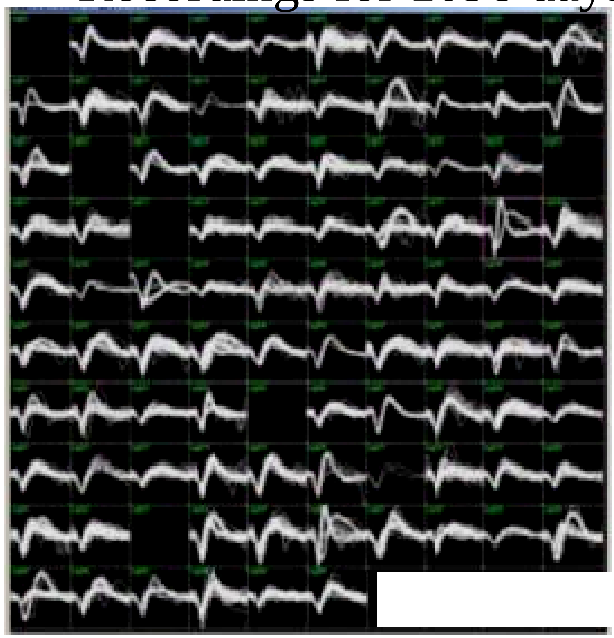




Recorded waveforms

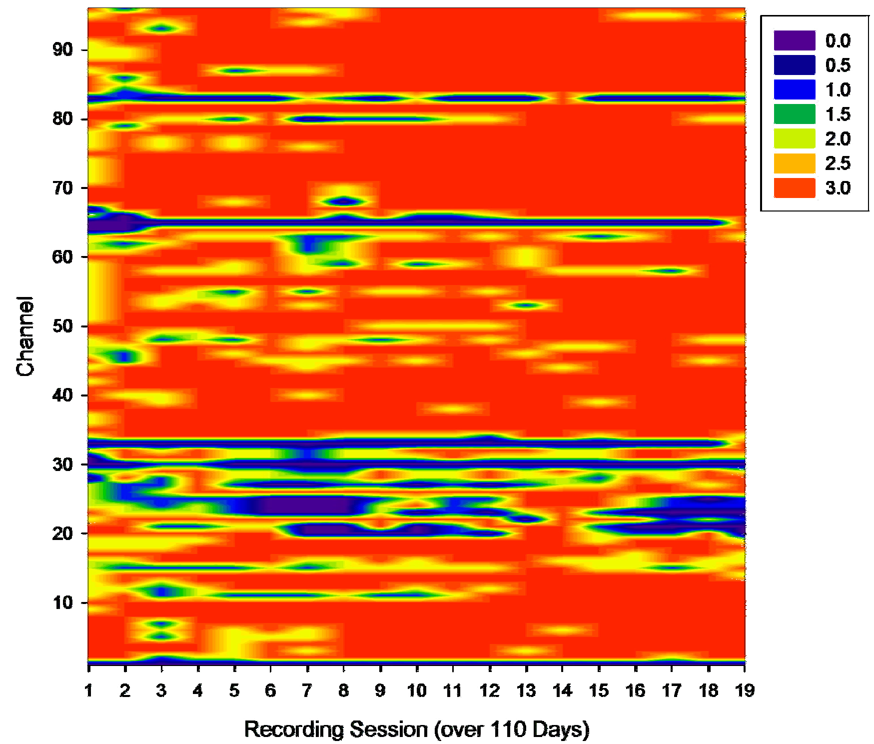
Chronic Implants

* 39 implants in 17 macaque monkeys
  (February 1996-April 2003)
* Recordings for 1098 days



n = 80± 7 in
3 recent MI implants

From: Selim Suner



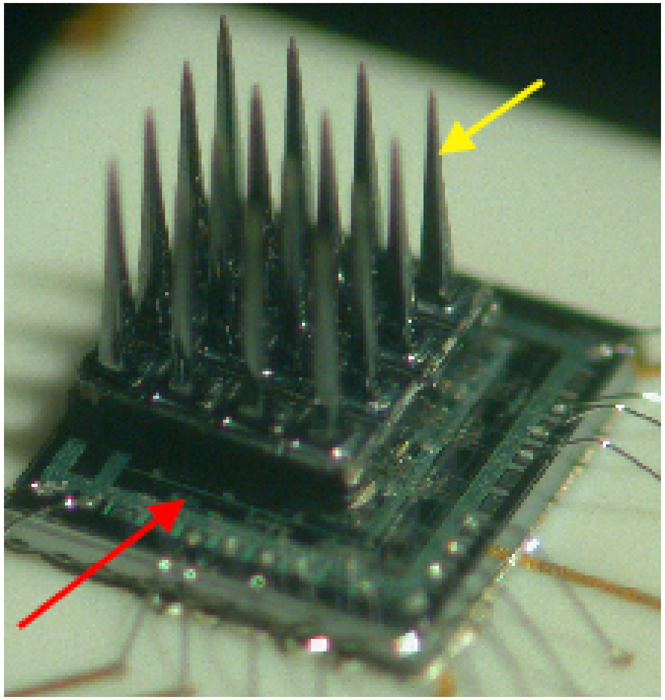
Many neurons every day (19 tests over 110 days)

Blue - no recording
Red - best recordings

Donoghue Lab

Implant Challenges

- Electronics
  - Miniaturization
  - Encapsulation
  - Telemetry
  - Heat dissipation
  - Low power
  - On board signal processing and spike sorting

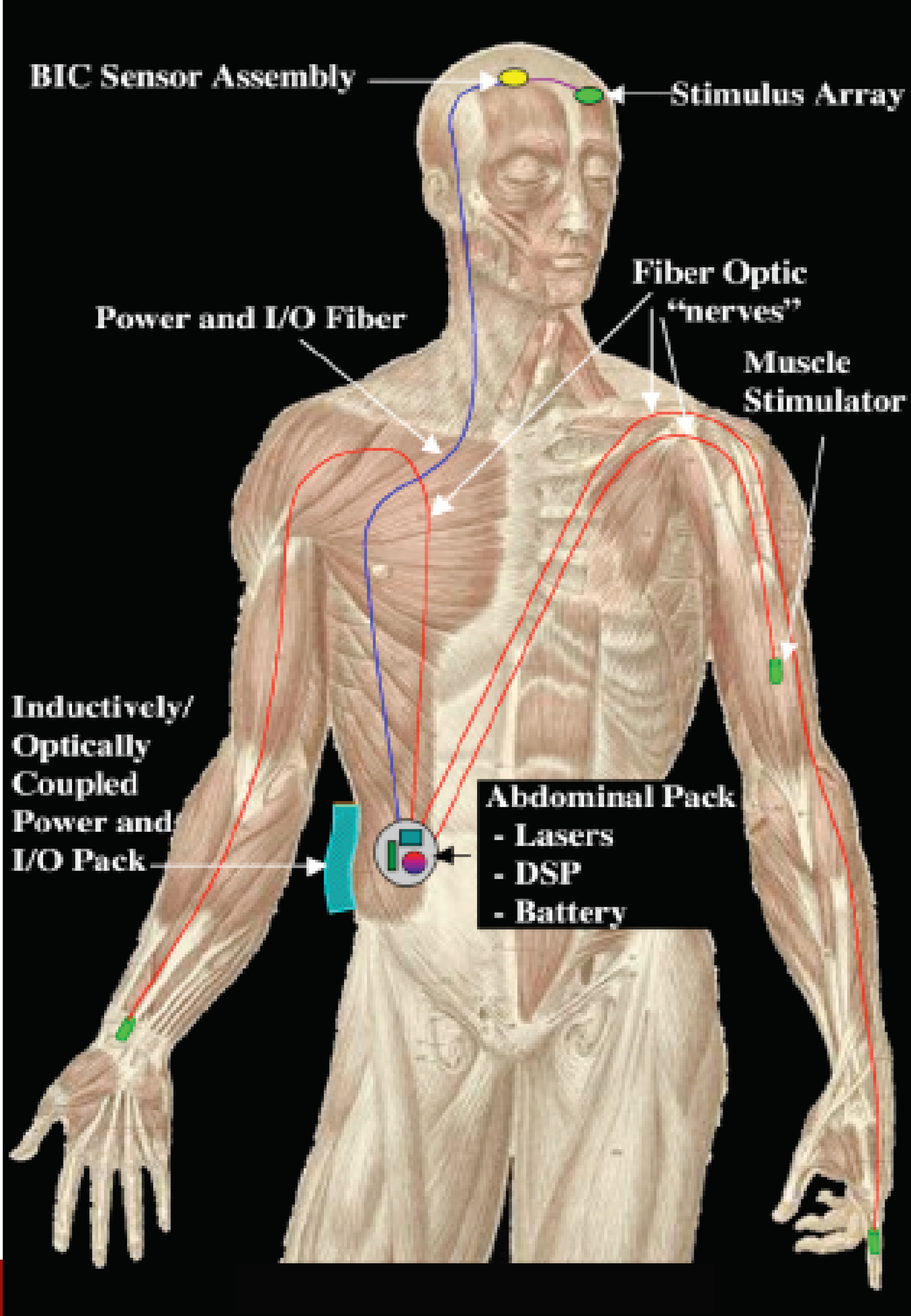


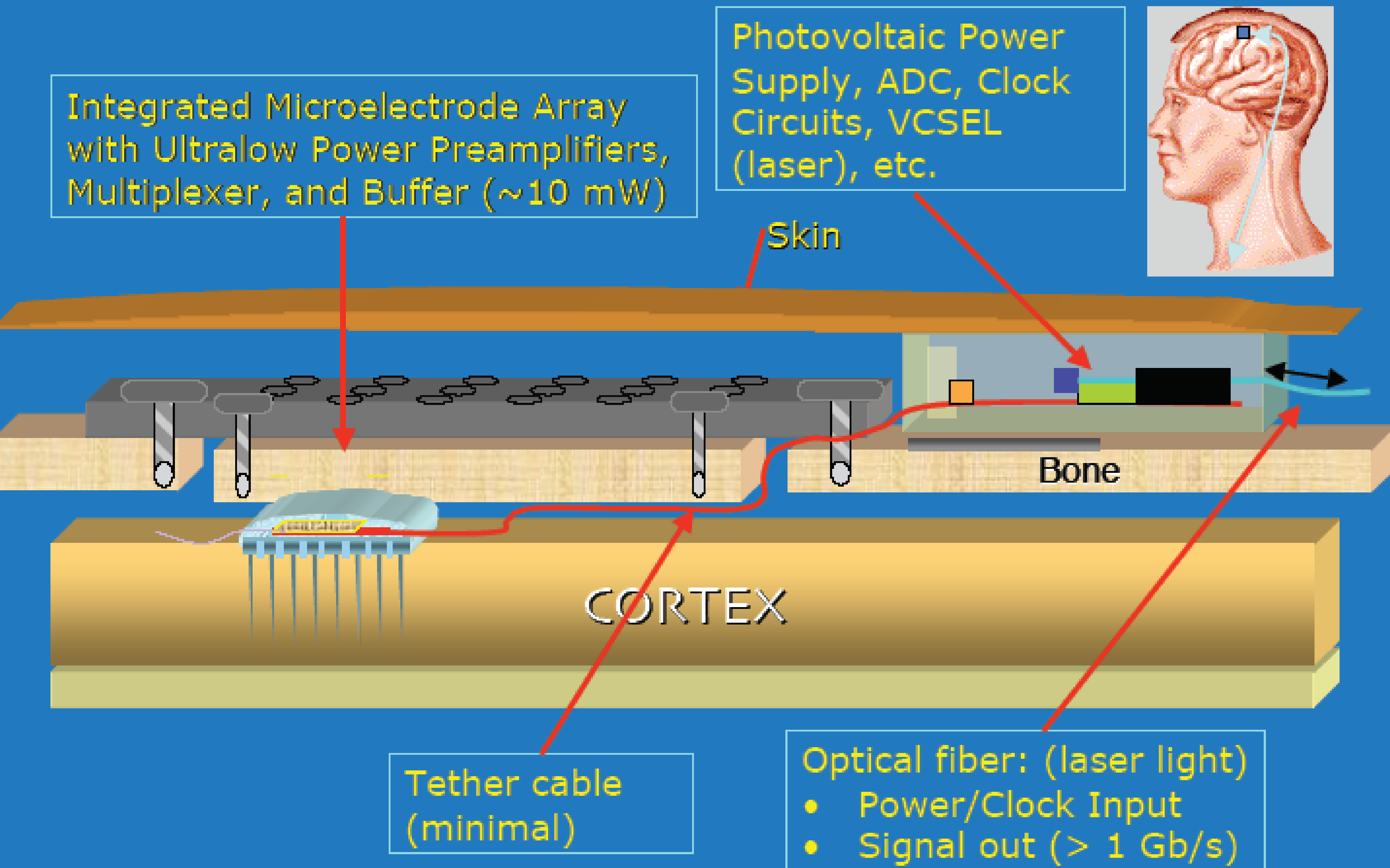
Nurmikko and Patterson

Chip-scale integration of array and electronics.

Long term vision

Nurmikko and Patterson

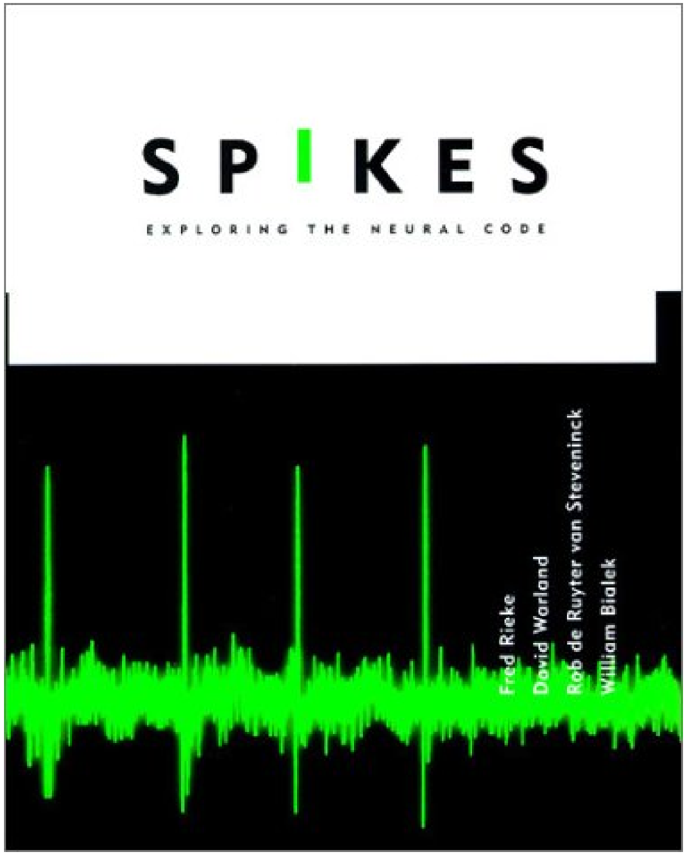




- OK also with other telemetries

What do the neural signals encode?

Language of the Brain

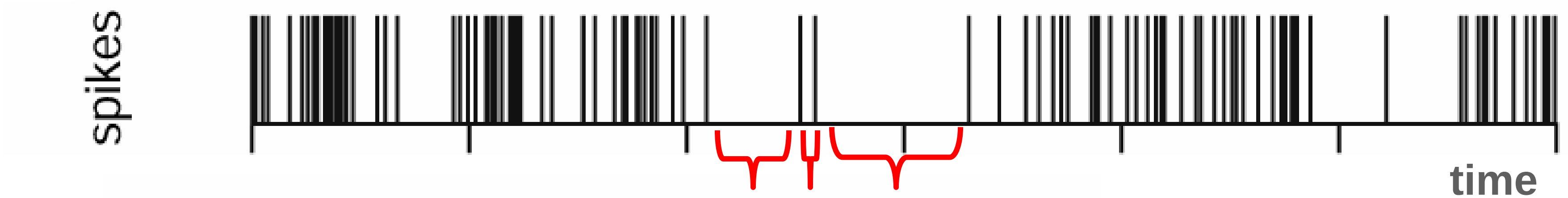


"If spikes are the language of the brain, we would like to be provide a dictionary… perhaps even providing the analog of a thesaurus."

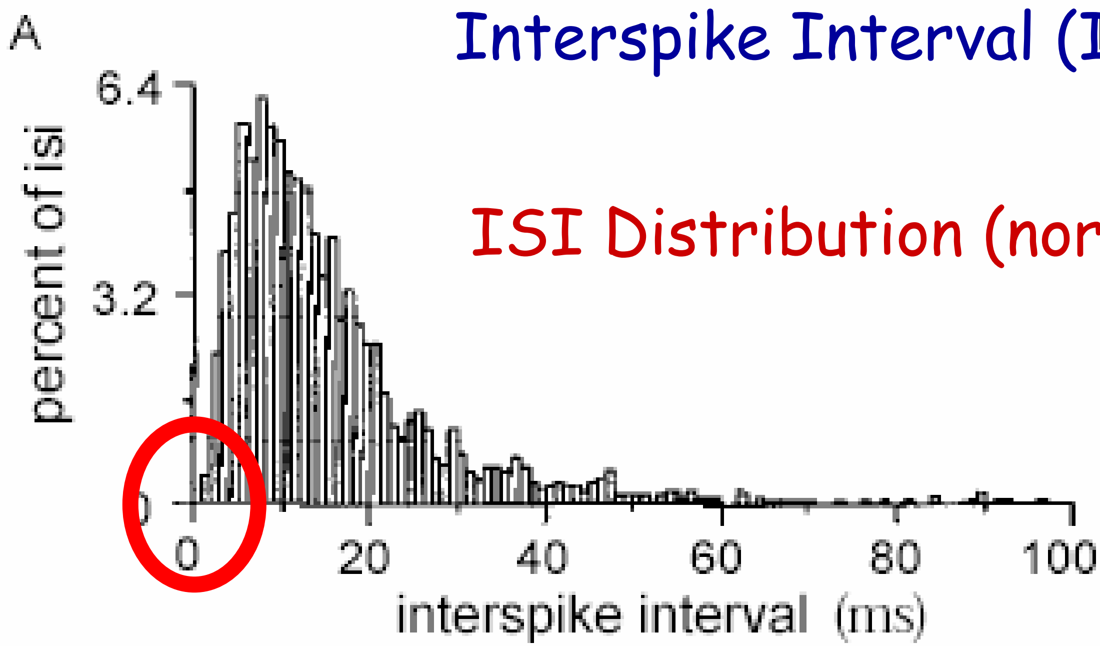
Rieke, et al 1997.

Some Terminology

Sequence of spikes from a single neuron = "spike train"



Interspike Interval (ISI)



ISI Distribution (normalized histogram)

Neural "Coding"

- How do cells represent information?
  - ie, how is representation "coded" in action potentials.

- If we understand the encoding then we can tackle the "decoding" problem.
  - inference – from activity to encoded property

Neural Coding

What are the possibilities?

You've got action potentials and now you want to represent "move the hand to the right". How might you do it?

Neural Coding

What are the possibilities?

1. Localist encoding in on/off response .
2. Rate coding.
3. Precise timing – pattern of spiking carries information.
4. Ensembles code information that individuals can’t.
5. Synchronous firing within and across ensembles (it is the interdependencies that matter).

Neural Coding

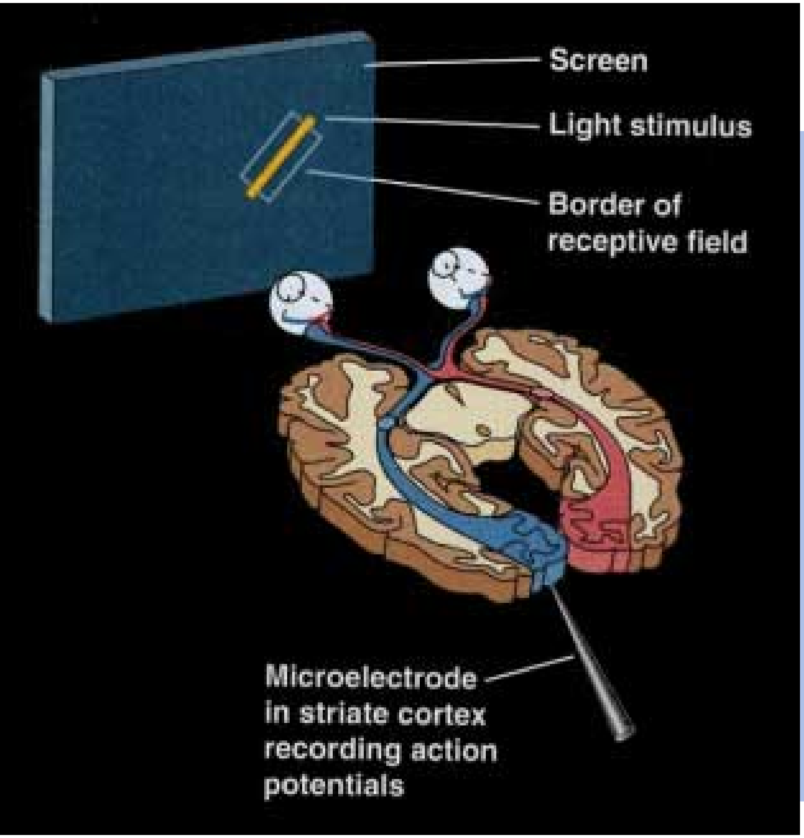
- **Localist** view – each neuron codes a particular value
  - "computer"-like model where neurons are binary
  - at the low level cells represent things like orientation
  - at the high level they represent complex information
- Problems?

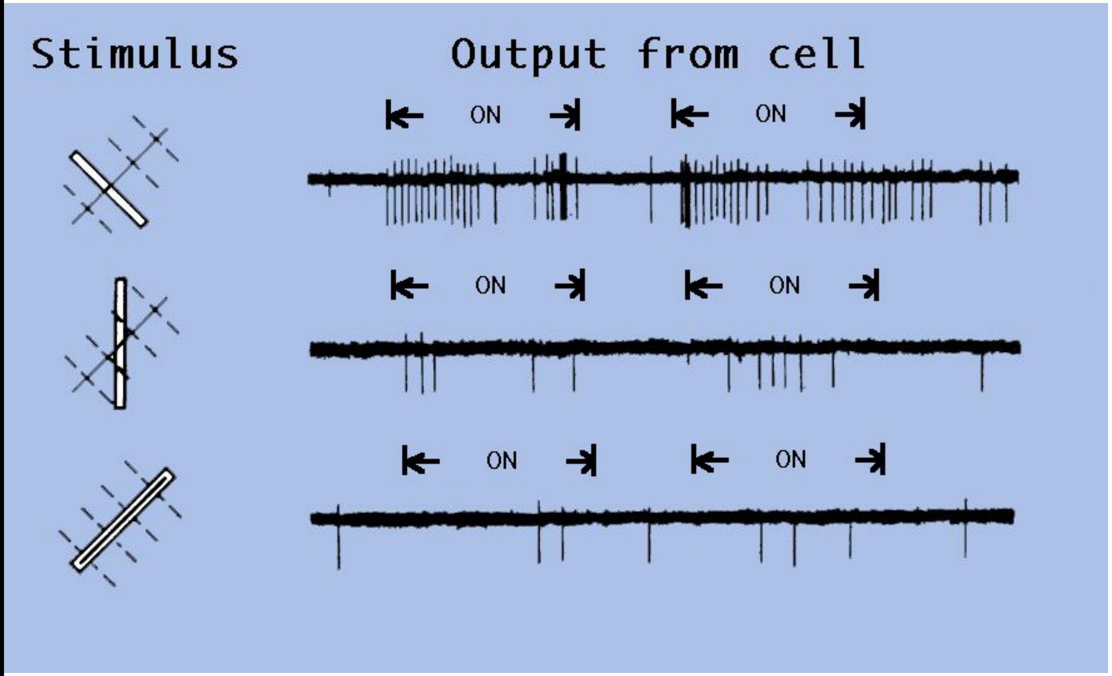
Neural Coding

Population codes

- distributed representation
- information encoded in the overall activity of many cells
- graded response – level of activity conveys information. Not binary.

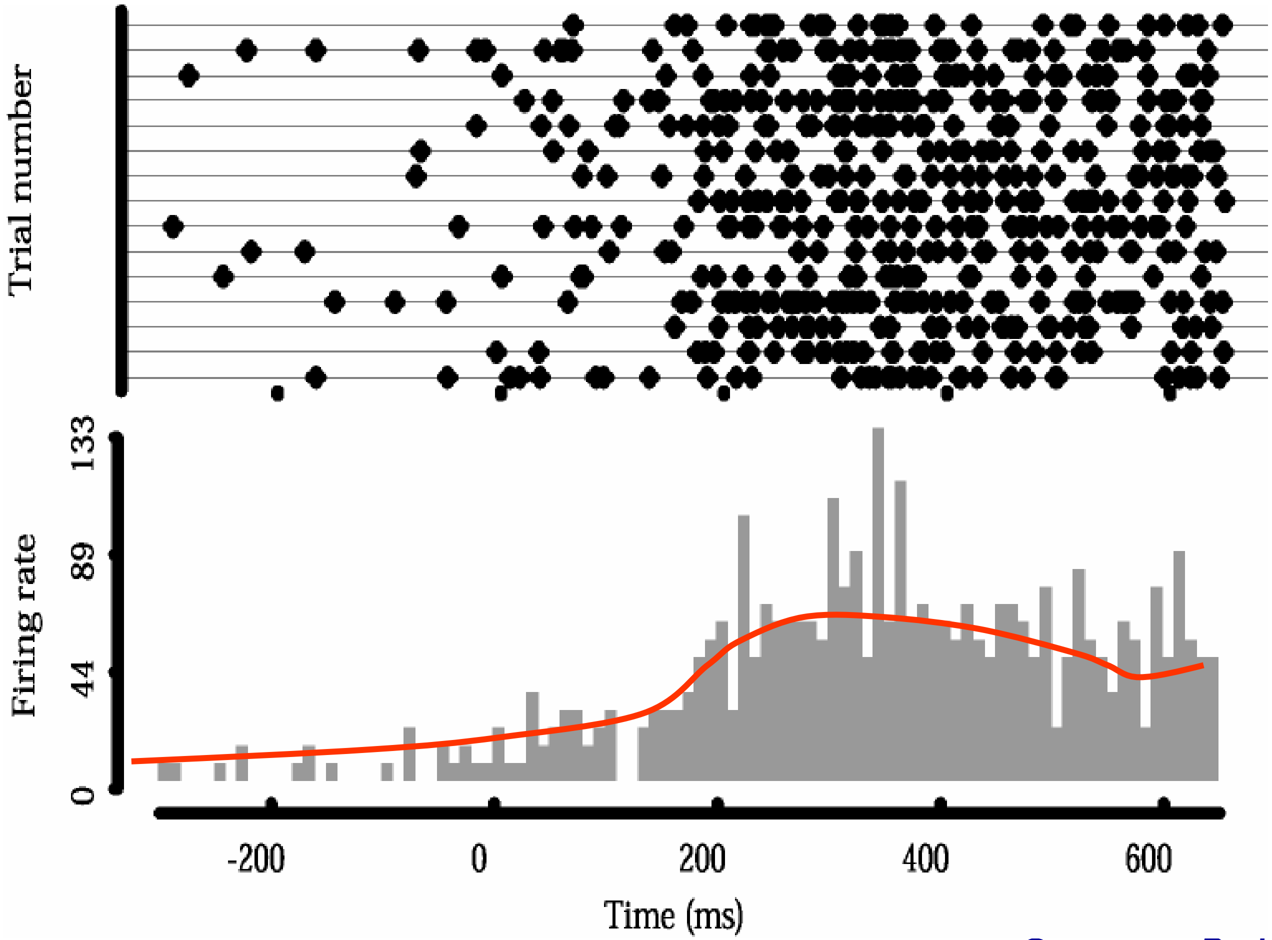
Orientation Selectivity





Hubel & Weisel, 1962

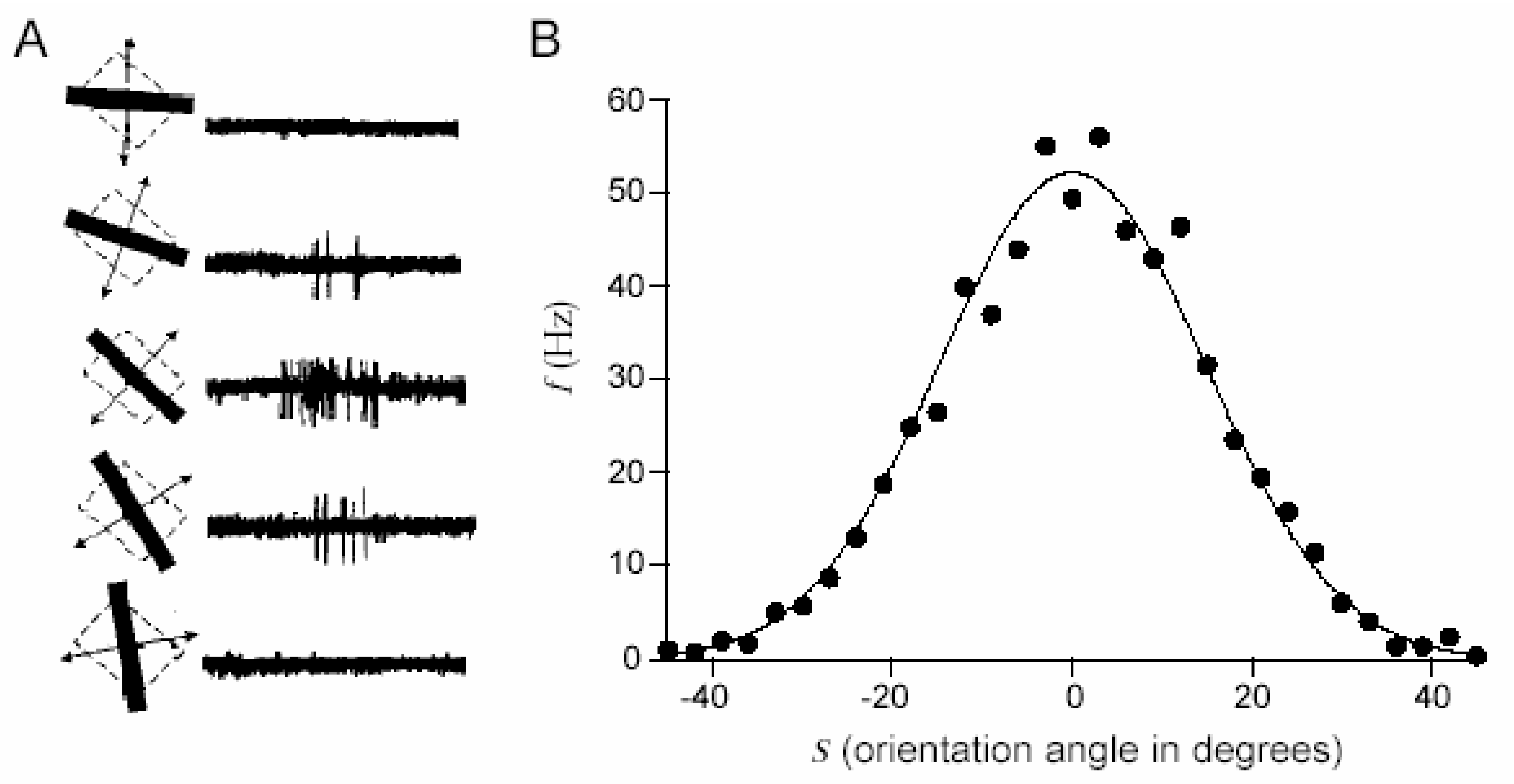
Cracking the Neural Code



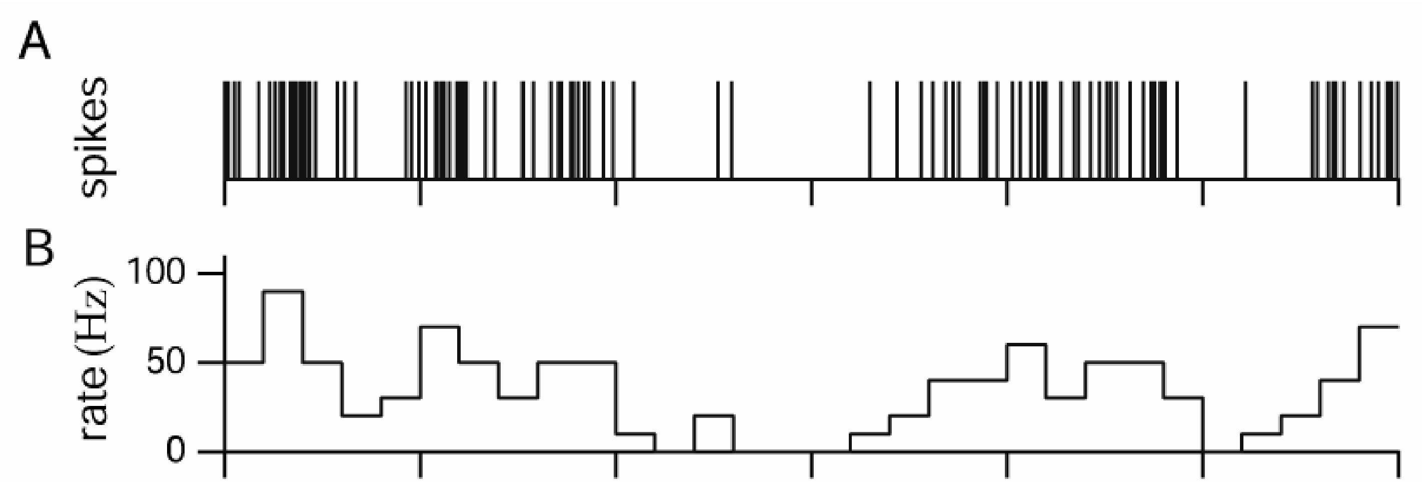
"rasters"

Source: Rob Kass

Orientation Tuning



Estimating Firing Rate



Source: Zemel & McNaughton, NIPS2000 tutorial

rate = (# of spikes in time bin) / (length of time bin)

Related to the probability a cell will spike (fire) in a given time interval.

Typically consider 50-70ms time bins.