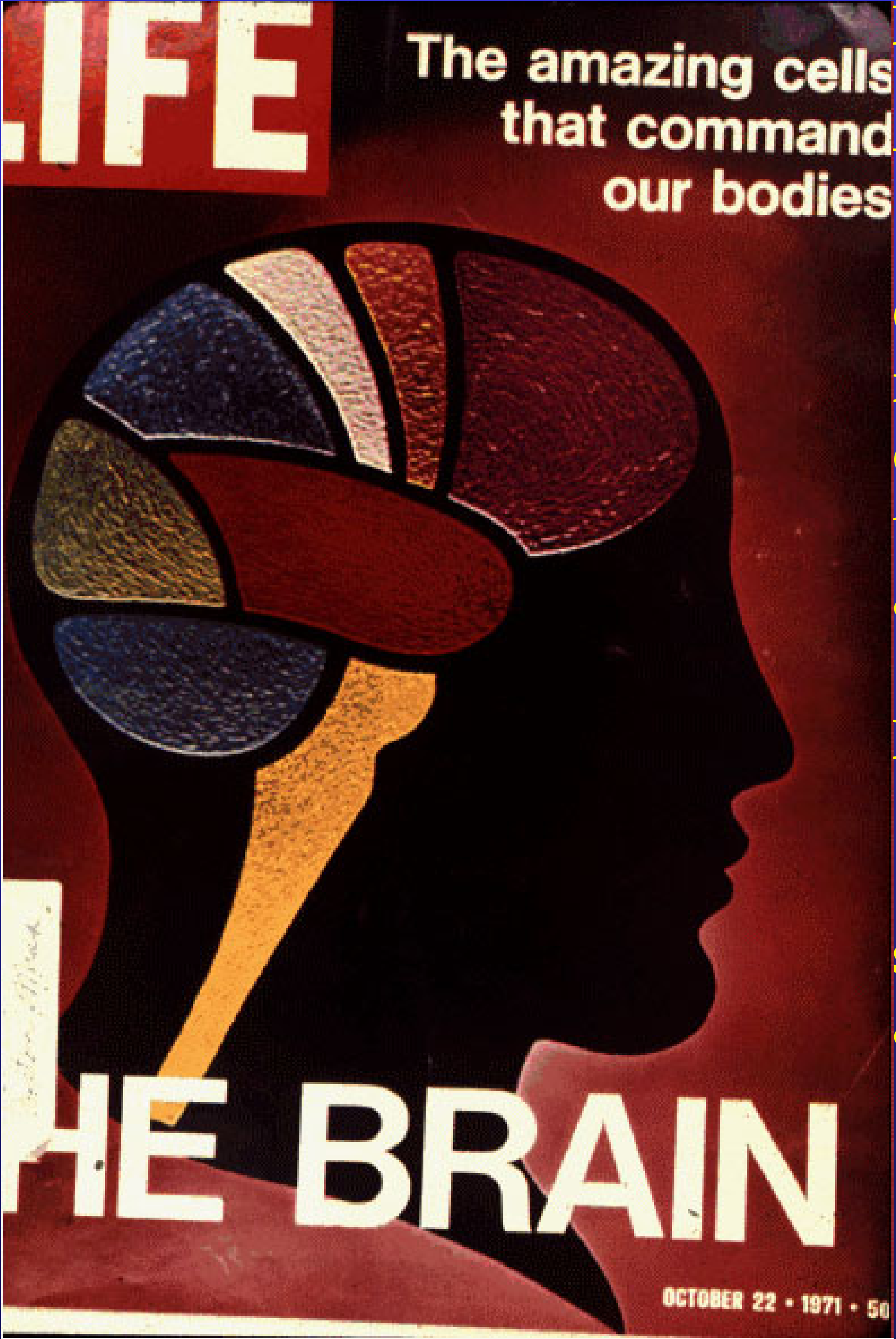


MOTOR CORTEX:

“Drama Queen of Motor Control”

Why?

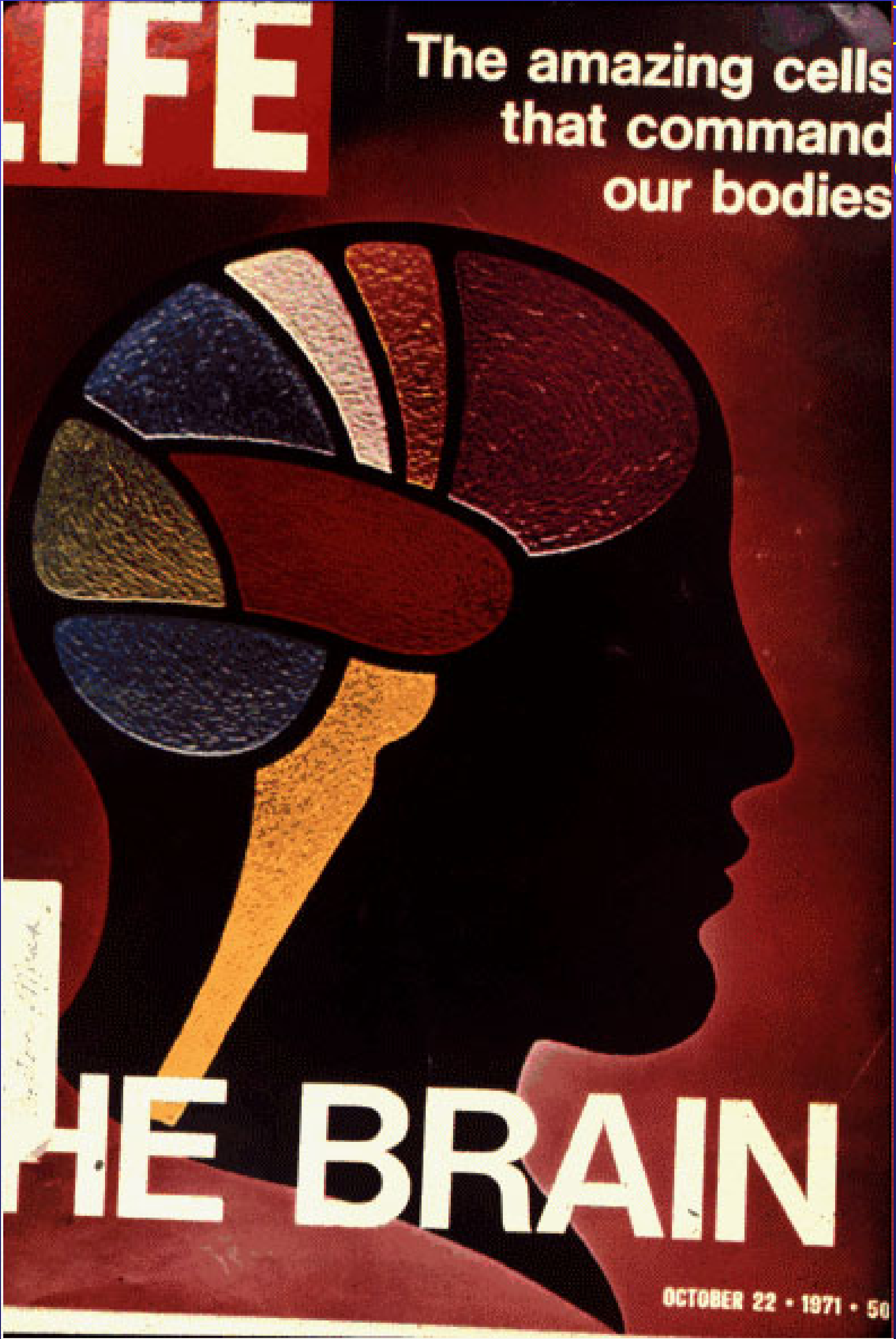
It’s up there pretty nakedly exposed, is big and powerful; is often damaged by any of many causes, often with disabling deficits therefore medically important, and an historic target for scientific study

But:

WHAT DOES IT DO?

What are the SPECIFIC command signals? These questions are still argued and debated.

How can a BETTER understanding help the patient? (Leads into next lecture by Dan Moran, and YOUR futures as medical scientists ;---)



MOTOR CORTEX

Cerebral Cortex and the Control of Voluntary Movement

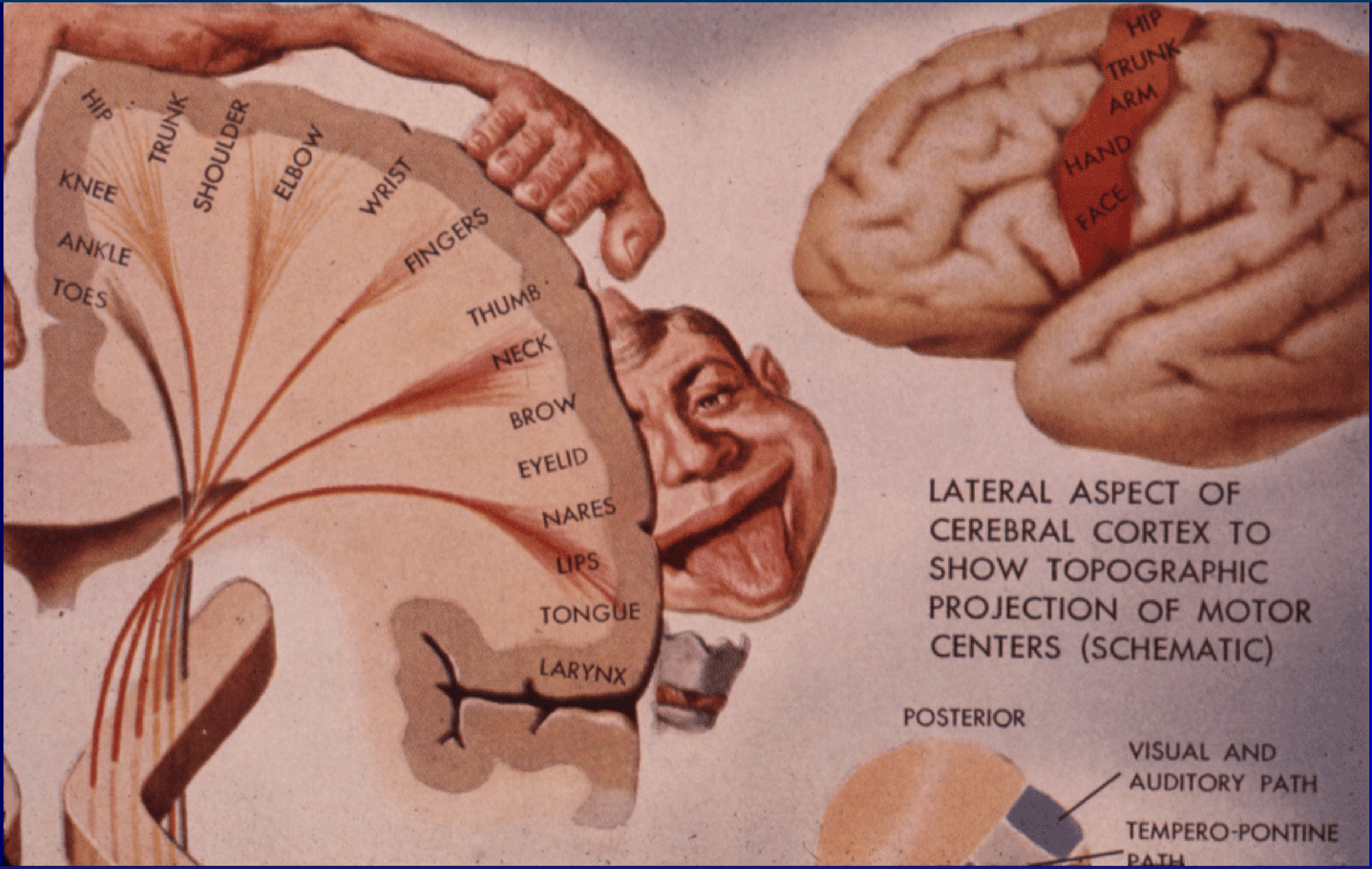
- Primary Motor Cortex, area 4, M1
- Secondary Motor Cortical areas SMA, PMC. PFC, Parietal
- Transcortical Reflexes, spindle, tactile
- Movement of single digits, pinch, grasp, digits sequences, mental movements.

OLD VIEW:

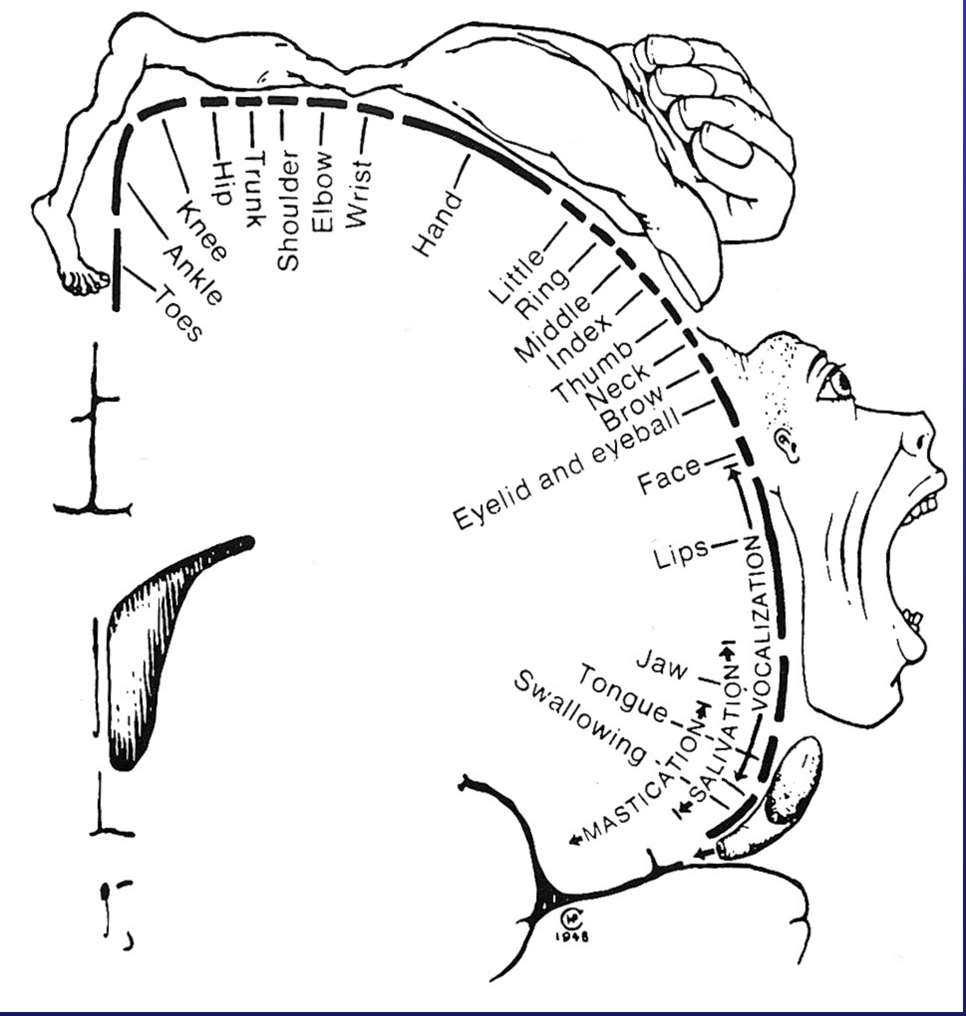
Primary Motor Cortex is strictly somatotopically organized:

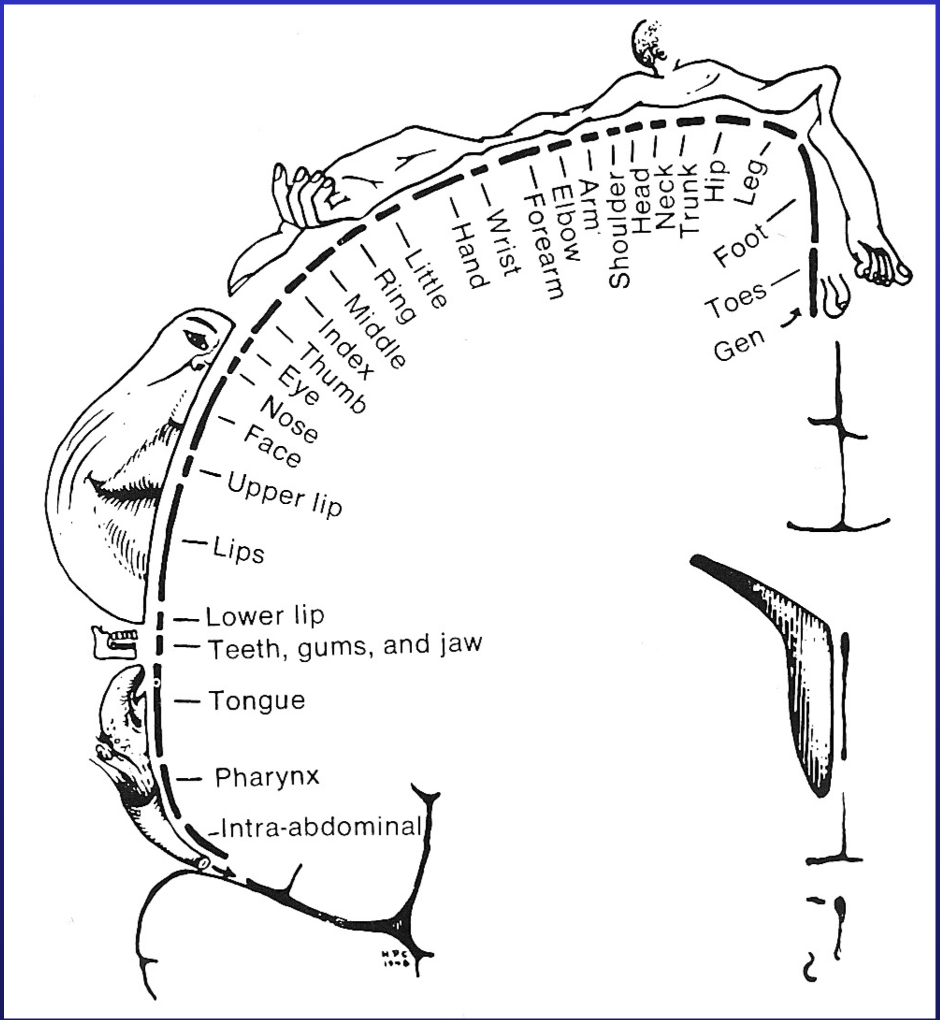
A focal seizure may start in face, spread to hand, then spread to foot.

Or foot->hand->face, or hand->foot+face. J.Hughlings Jackson, 1870.

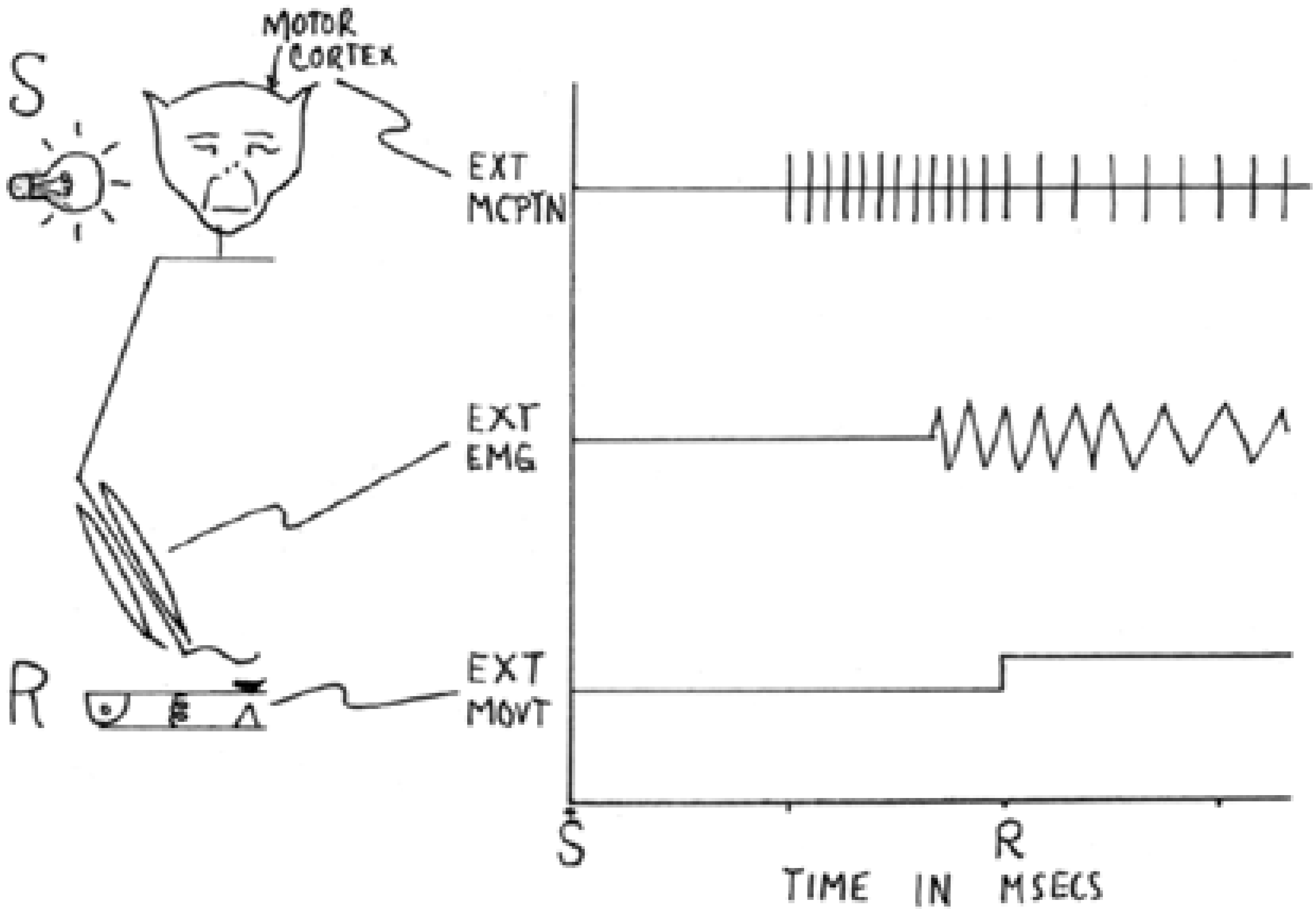


Cartoon from the electrical stimulation of human cerebral cortex (1950's) showing somatotopic localization in motor cortex (left) and somato-sensory cortex (right). But it is OVER-DETAILED: a cerebral cortical lesion may impair movement or sensation in face OR arm OR leg, but NOT A PART of face OR arm OR leg.





The paradigm developed by Ed Evarts (generously attributed to Ricci, Doane and Jasper). S, stimulus. R, response. MCPTN, extensor CST neuron.



MCPTN's coding for MPAT + Force (1/3), JPOS (1/3), and DSET (1/3) (Evarts; Thach)

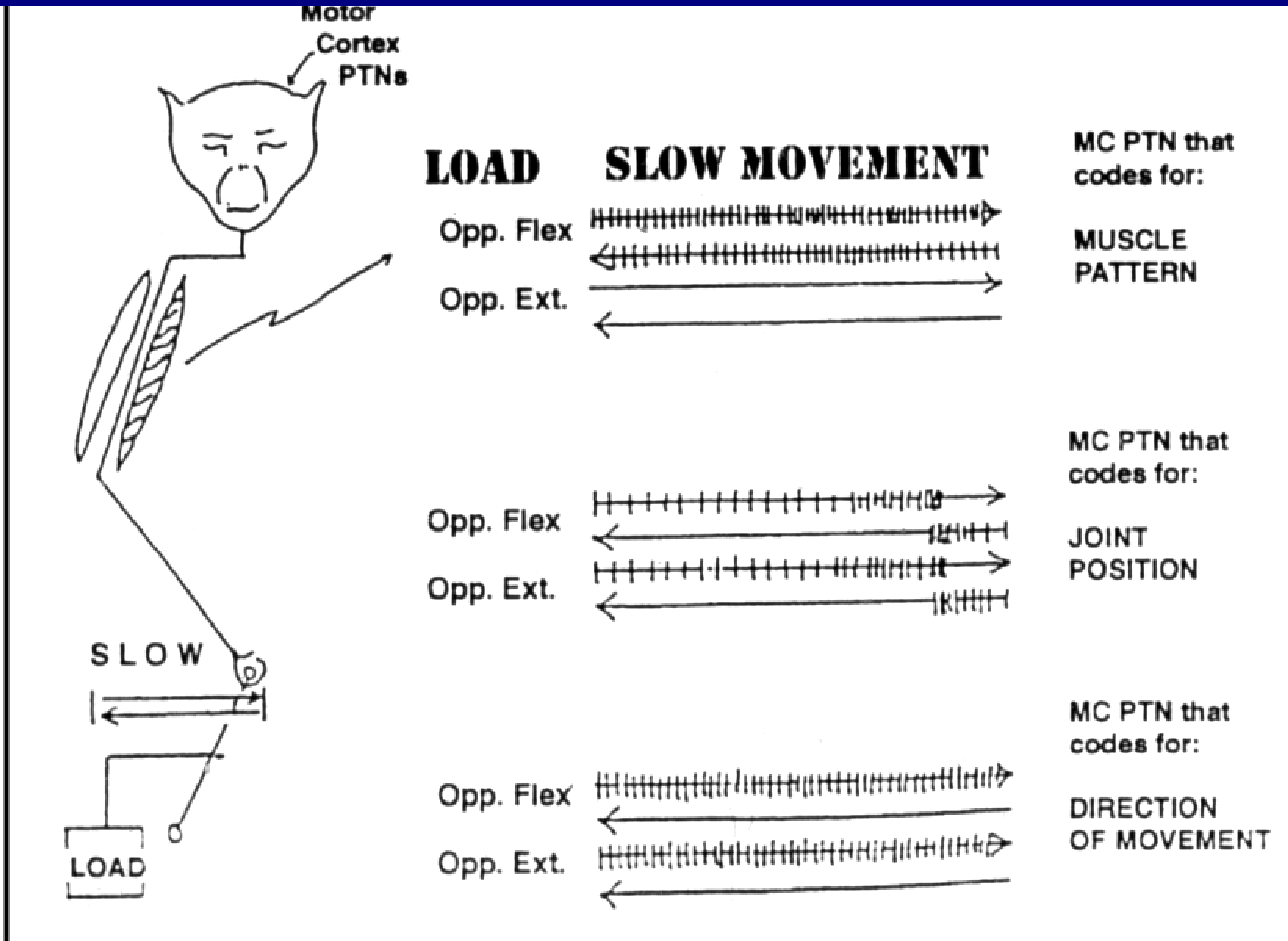
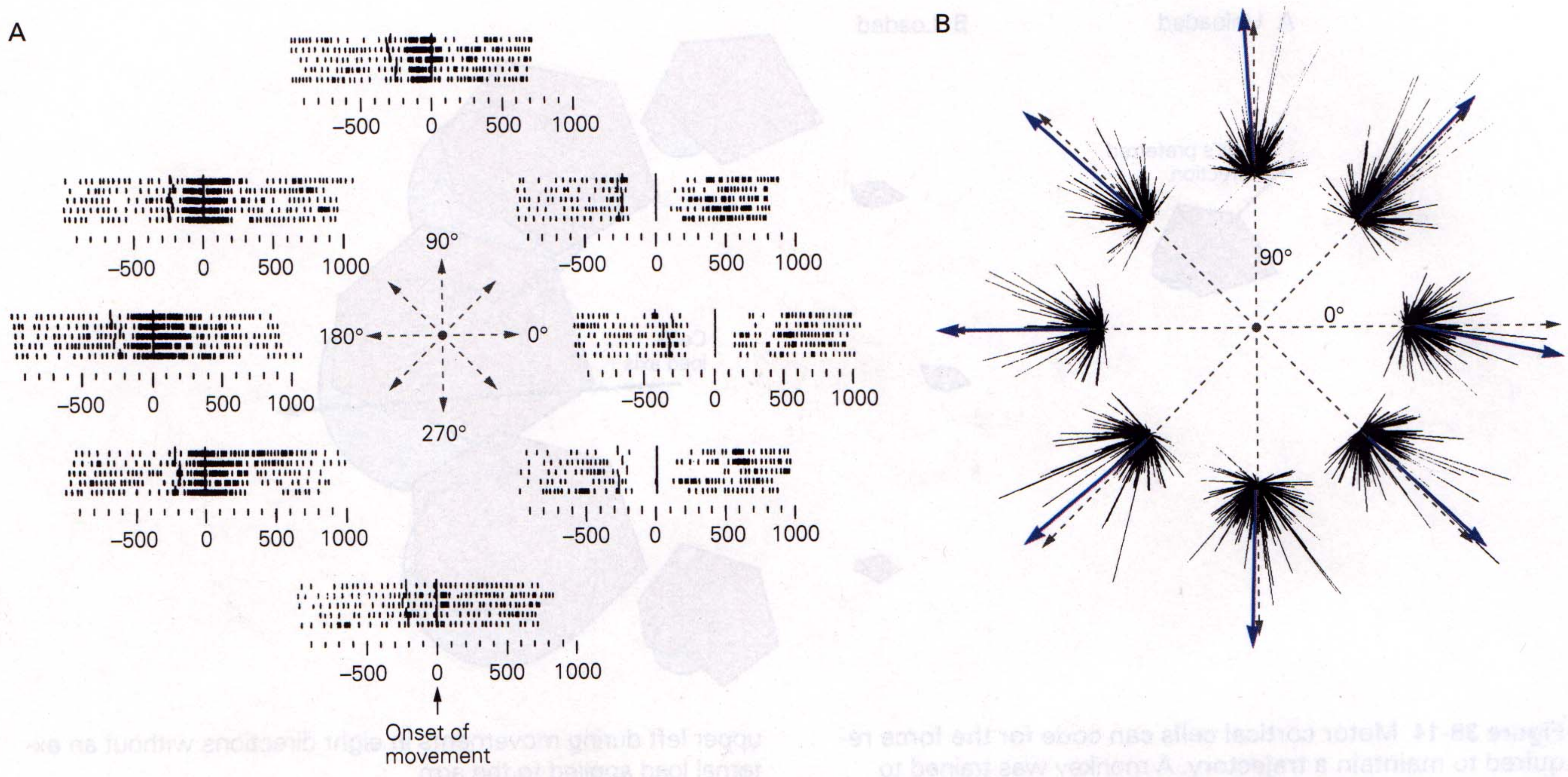


Figure 4.

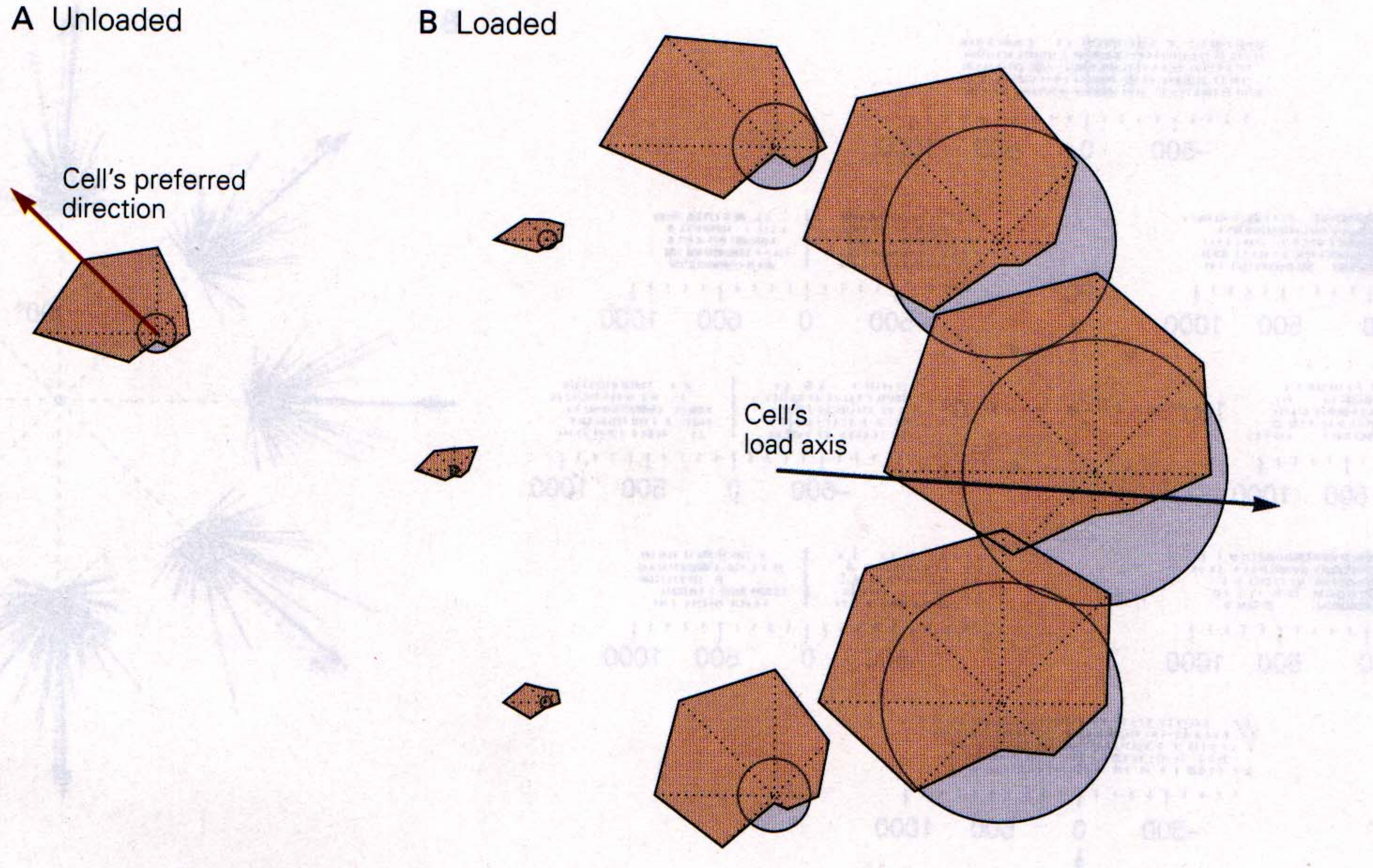
Georgopoulos:

DIRECTION is the primary output code from motor cortex

(But see Kalaska)



Georgopoulos: DIRECTION is the primary output code from MC Kalaska: LOAD, also. EMG looks like the MC "direction" code unless one does the load/joint position/movement direction dissociation (Dan Moran will discuss these coding issues in further detail in his lectures)



HOW DO WE KNOW THE MOTOR CORTEX CAUSES MOVEMENT?

l. Lesions impair movements, especially voluntary movement of single joints.

2. Electric stimulation causes movements of single and multiple joints.

3. Neurons in motor cortex fire before the onset of muscle action and movement.

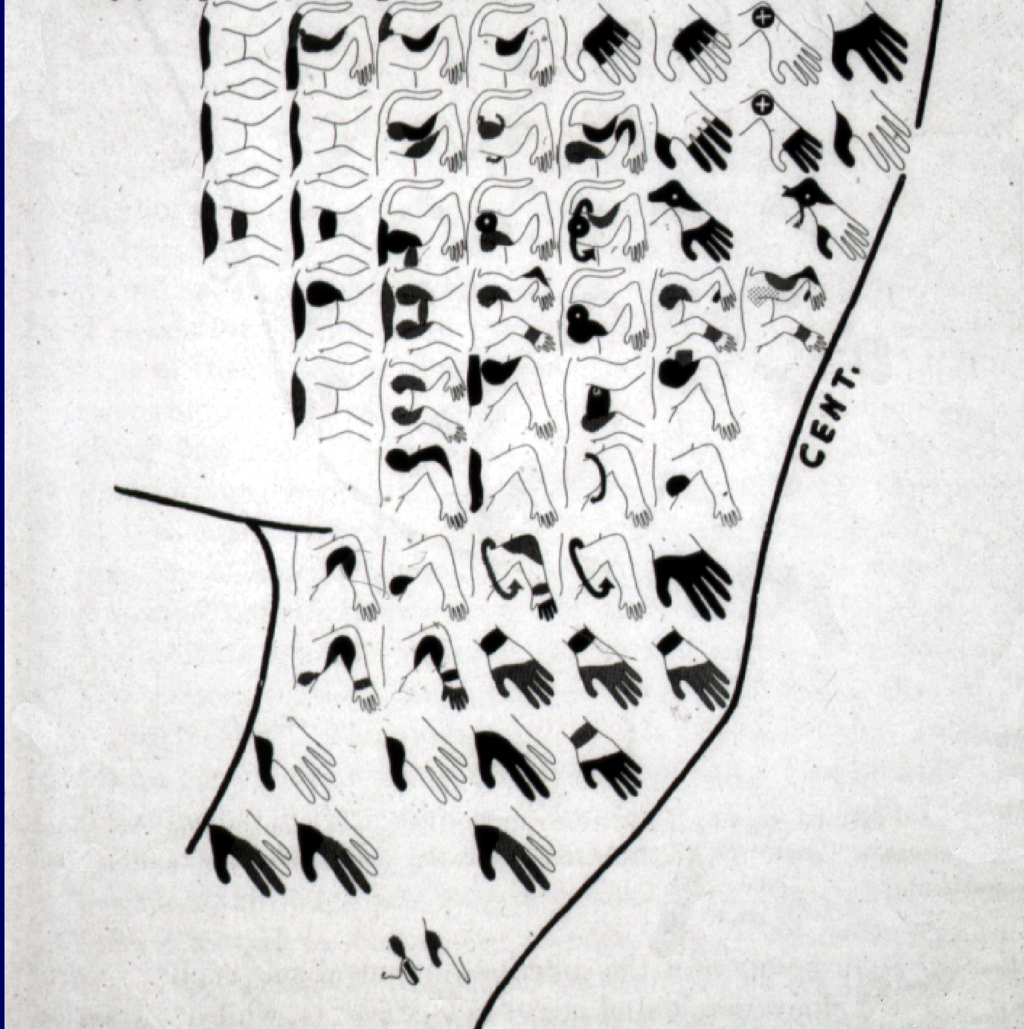

Motor simiusculi

NEW STORY BEGINS:
Monkey Primary Motor Cortex
Stimulation studies of
Clinton Woolsey, 1950's

Primary motor cortex
= M1, area 4 and
Secondary Motor Area
= M2, SMA, superior area 6

M1: distal body parts (posterior, buried in central sulcus) have a larger representation than proximal body parts (anterior, surface).

M2: Representation is more diffuse than in M1



(Stimulation studies of Clinton Woolsey).

ACTUAL DATA:

Note that stimulation at any on Site caused movement at a number of joints. How then does motor cortex cause movement at SINGLE joints??

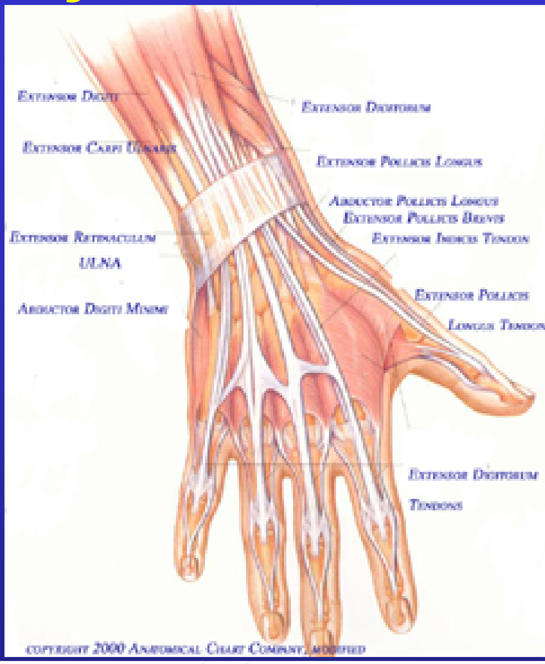
How do we move digits individually?

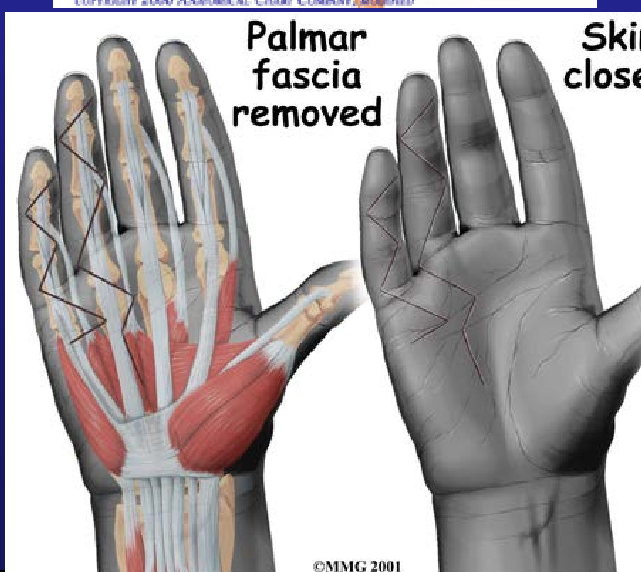
Lesions of Motor Cortex and CST preferentially impair movement of

single joints.

How do we move digits individually?

Lesions of Motor Cortex and CST preferentially impair movement of single joints.



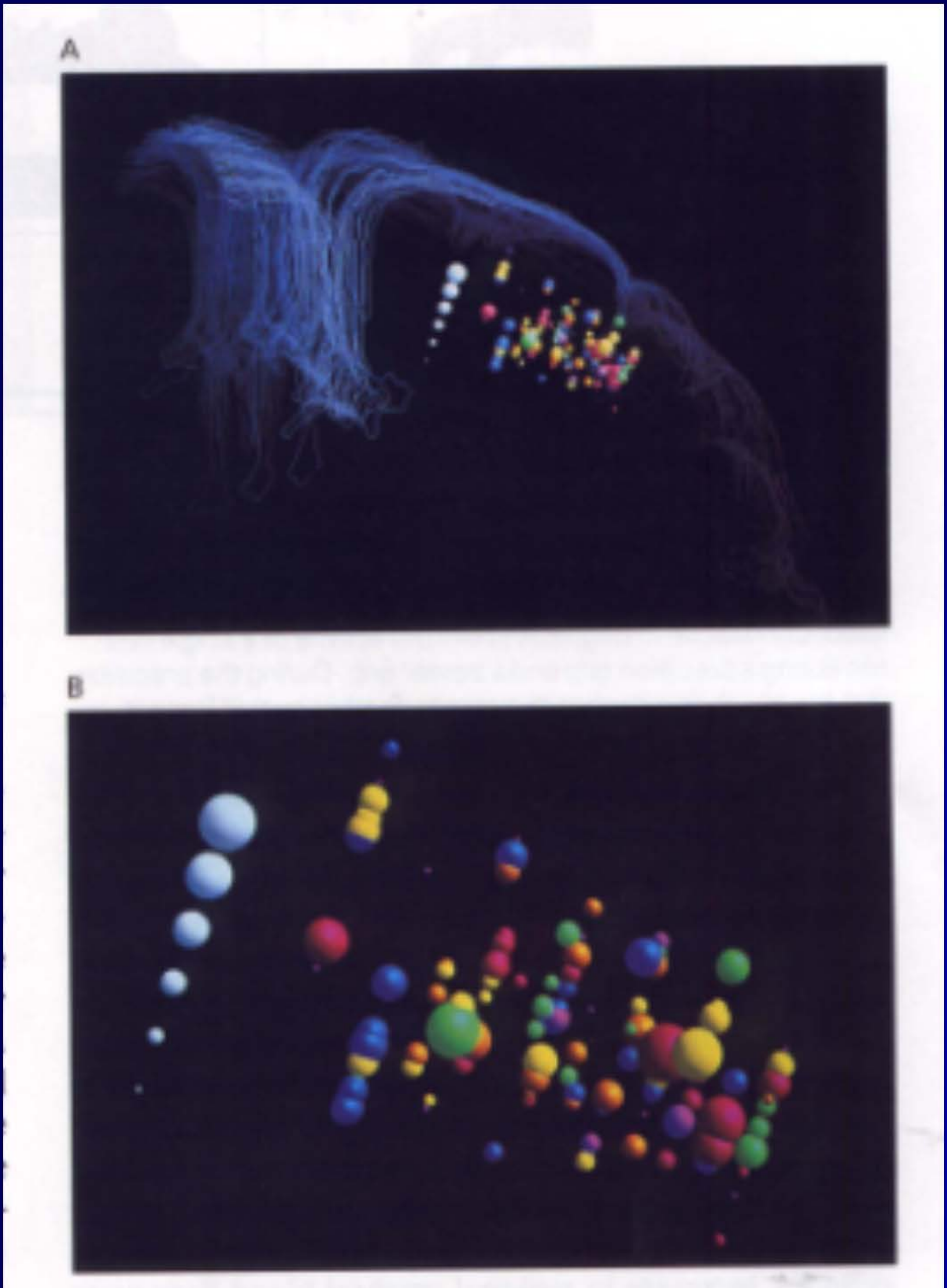


And especially, F/E movements of digits 3, 4, & 5.

WHY?

Digits 3, 4, & 5 share common long flexor and extensor muscles, and are thus mechanically constrained. CST works with parts of muscles (motor units) and muscle combinations to GIVE independent movements to these digits in humans. TO MOVE ONE DIGIT IT IS NECESSARY ACTIVELY TO HOLD OTHER DIGITS STILL (Schieber).

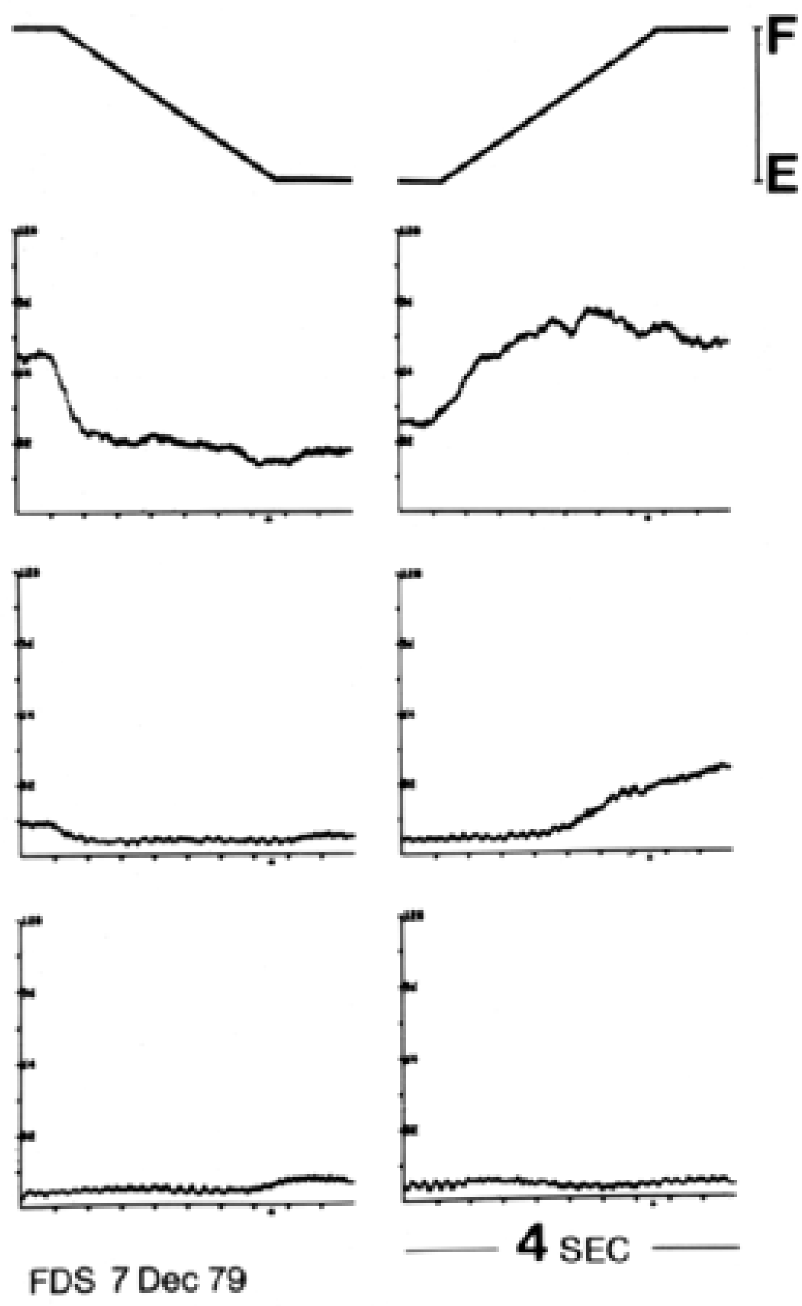
Paradigm for studying single digit movement in monkey (Schieber)



MC location of neurons firing during single digit movements: SOMATOTOPIC, BUT WITH OVERLAP (Schieber)

Left to right: interhemispheric fissure,
white dots scale firing frequency
0, 40, 80, 160, 200 spikes/sec

colored dots indicate which digit
1 thumb red
2 index magenta
3 middle yellow
4 ring green
5 little blue



EMG from a forearm flexor(FDS) during wrist extensor movement (left) and flexor movement (right)

under torque loadings:

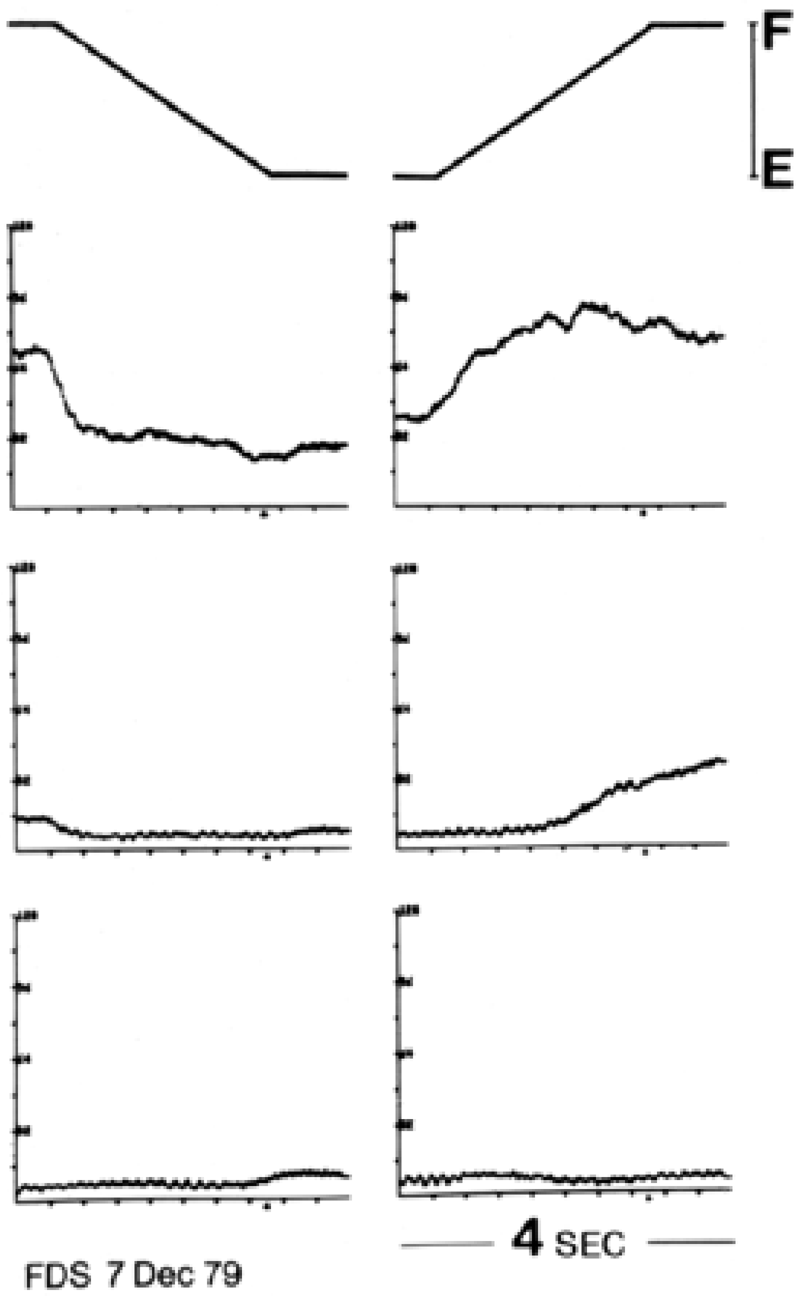
opposing flexion (top EMG)

no load (middle EMG) and

opposing extension (bottom EMG)

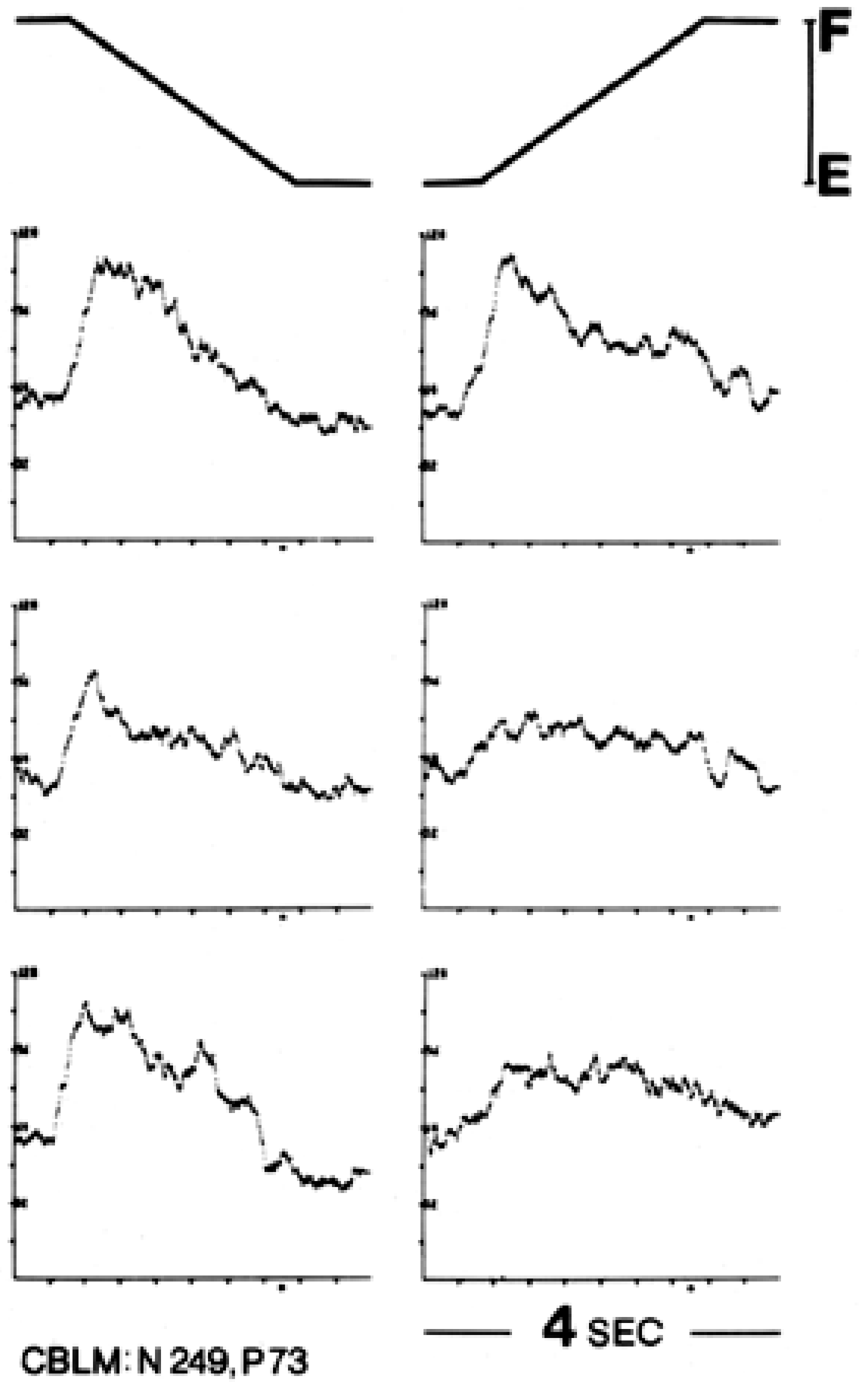
The flexor muscle is active both in flexor movement excursion AND under flexor torque load.

(Schieber)



Some neurons in Motor Cortex had discharge patterns similar to those of EMG of wrist flexor or extensor muscles

(Schieber)



Other neurons in Motor Cortex (and all those in cerebellar nuclei) had discharge patterns that during wrist movements in

OPPOSITE DIRECTIONS

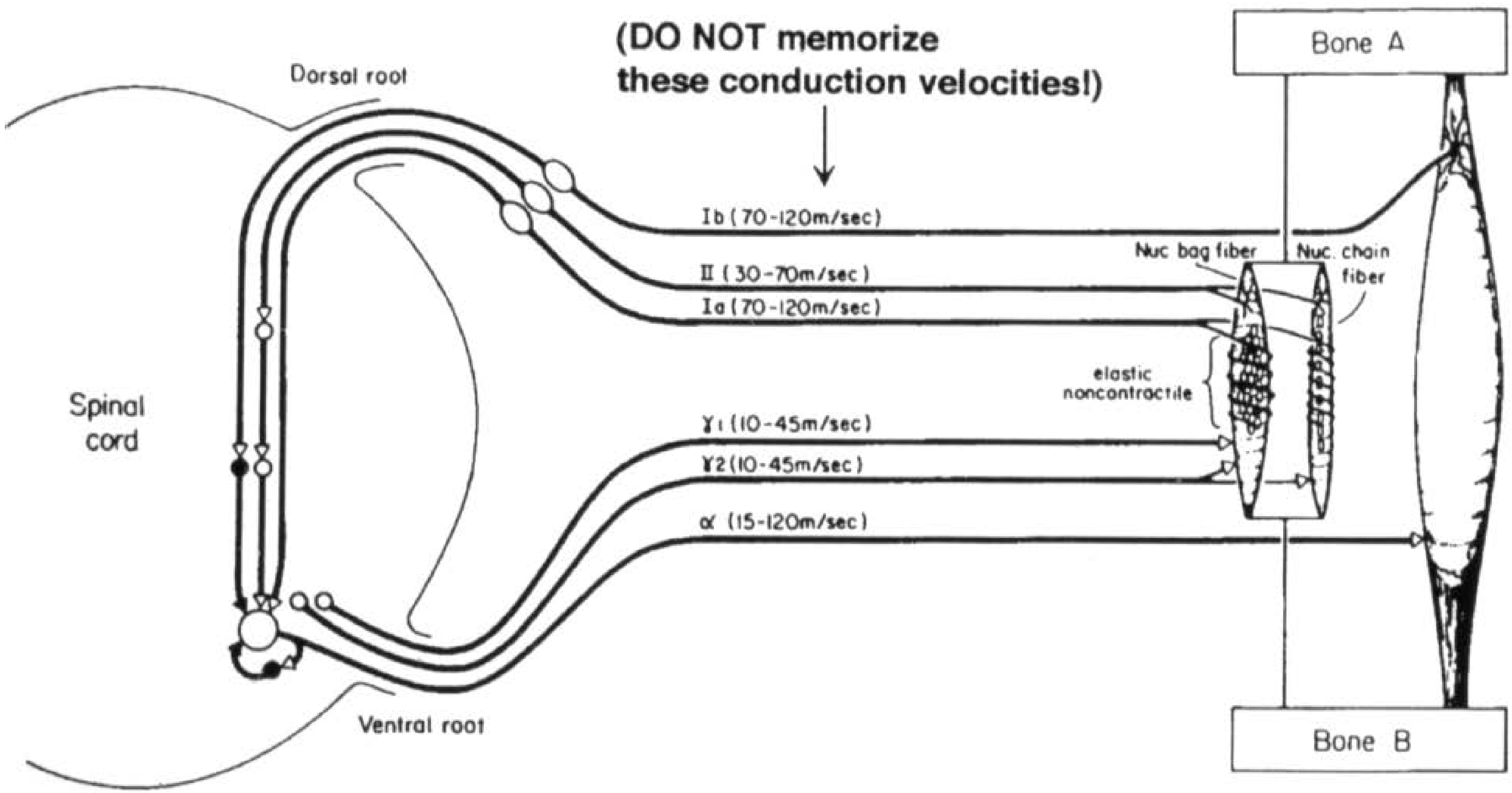
and under

OPPOSITE TORQUE LOADS

were conspicuously bidirectional.

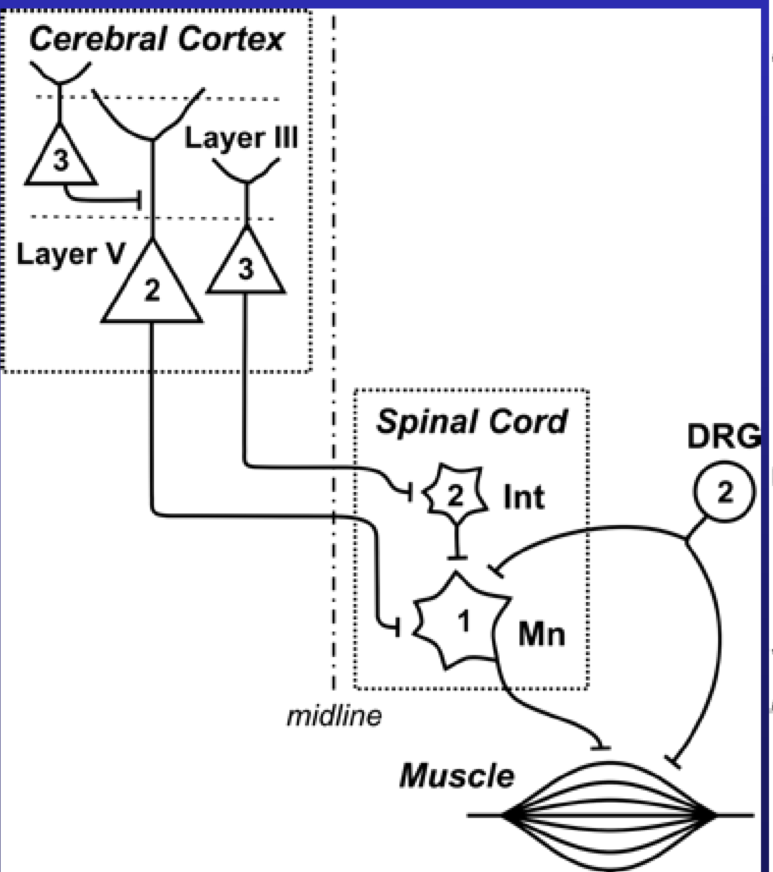
(Schieber)

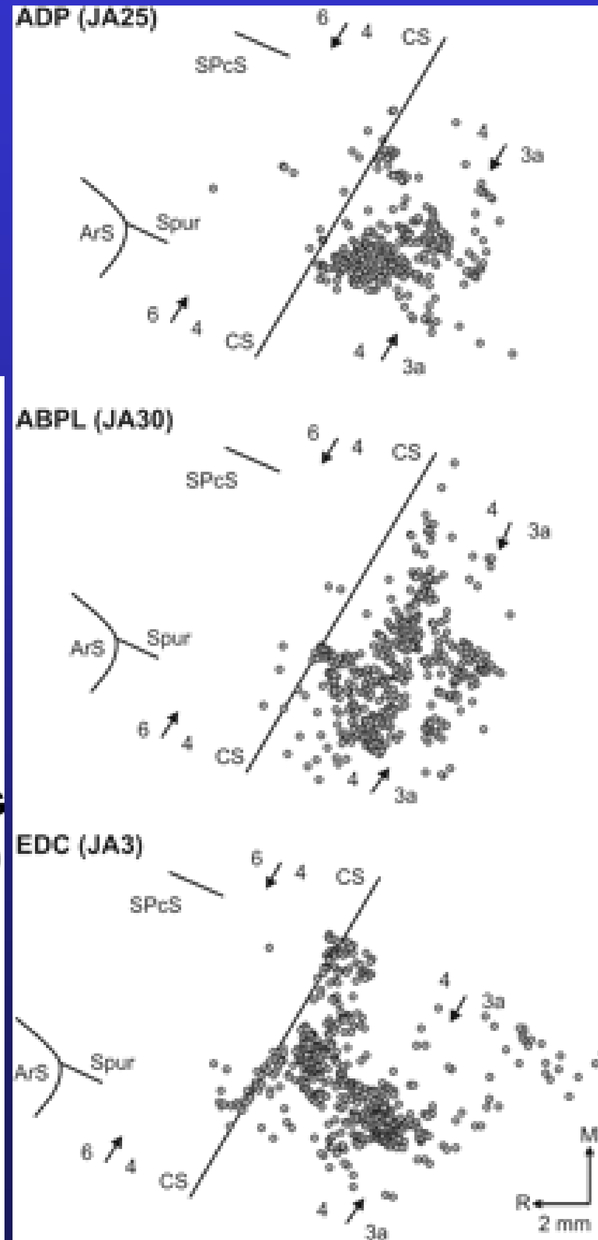
Muscle Spindles and the "Rule of Two's": 2 (+) types of spindle fiber, two types of spindle receptor, two types of spindle afferent, two types gamma motor neuron that control spindle sensitivity to stretch

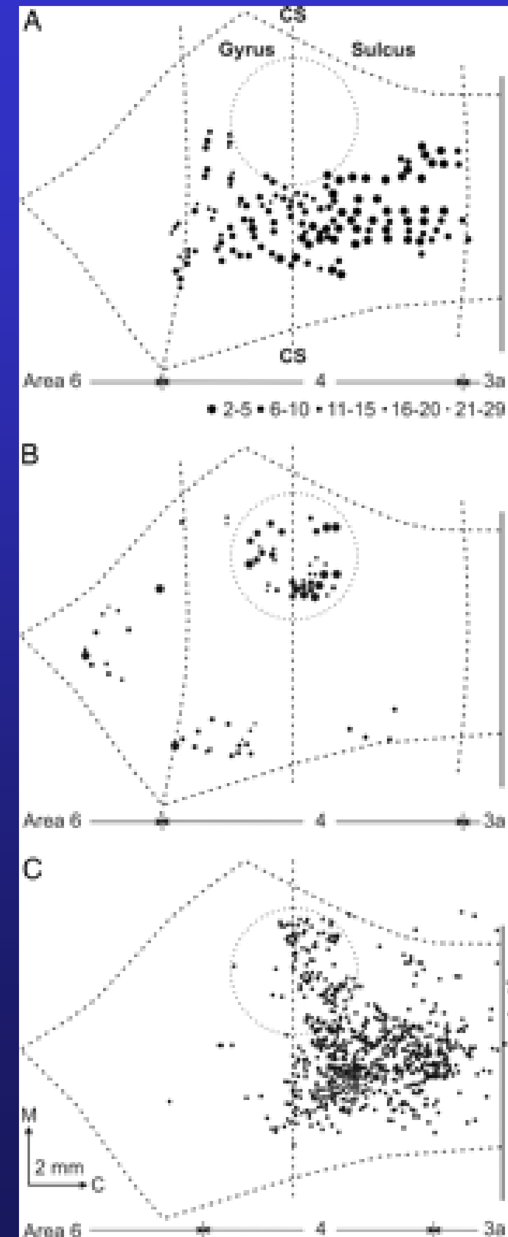


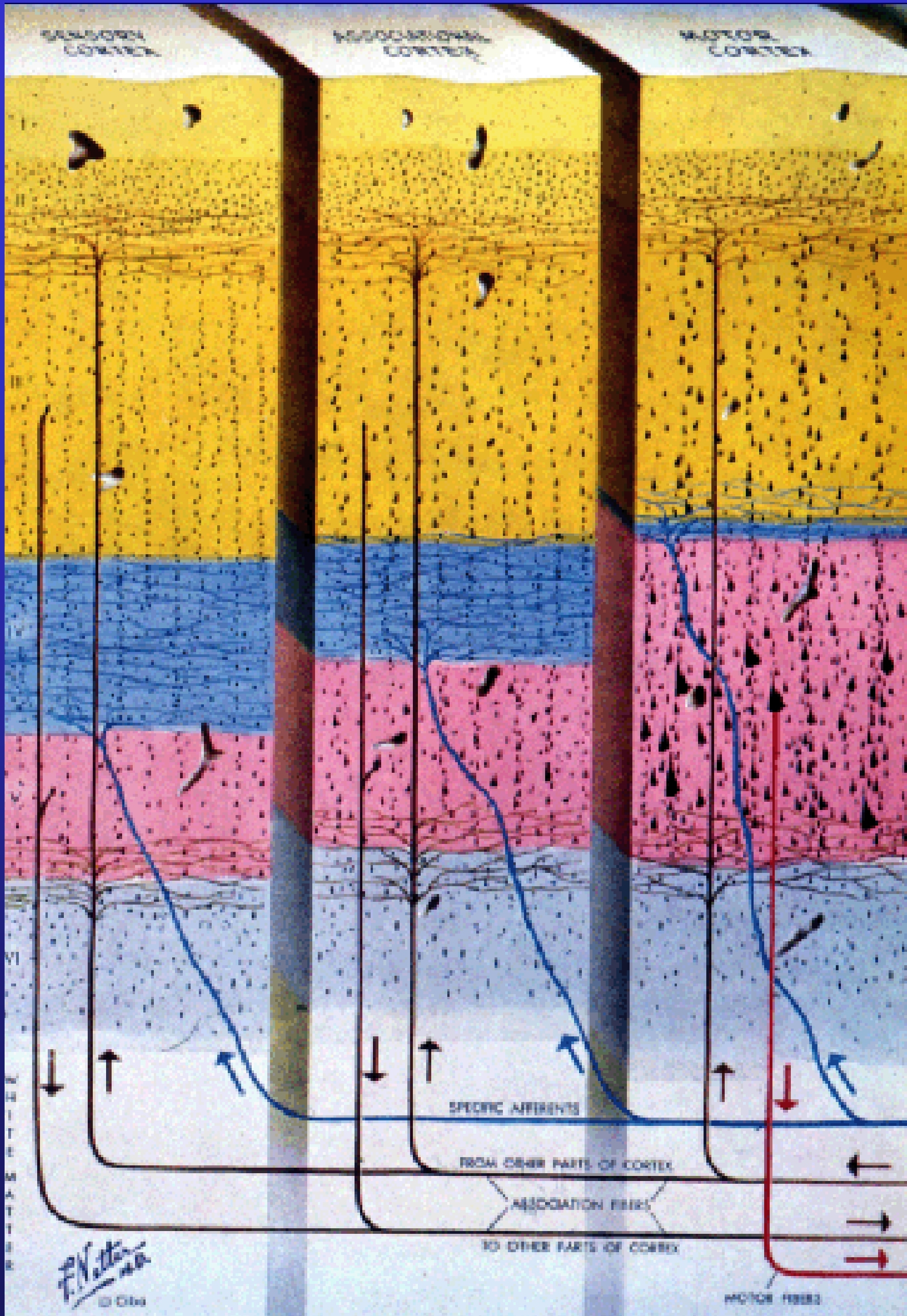
Rathelot & Strick '07 Retrograde rabies virus labeling from muscle → motor cortex:

Muscle control: spread rather than focal









I

II

III

IV

V

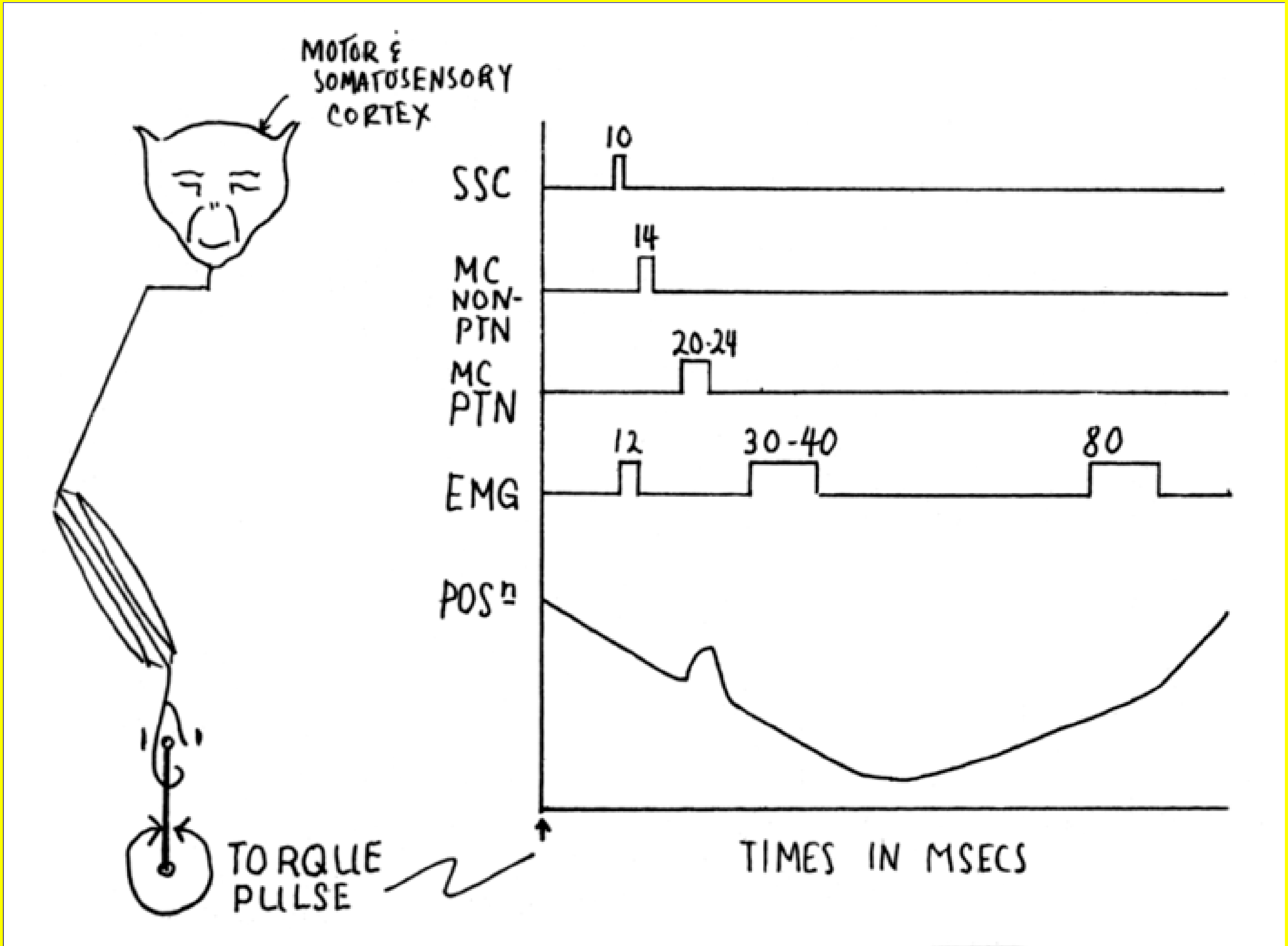
VI

Cerebral Cortex: Sensory, “Association”, and Motor. Inputs from cerebral cortex

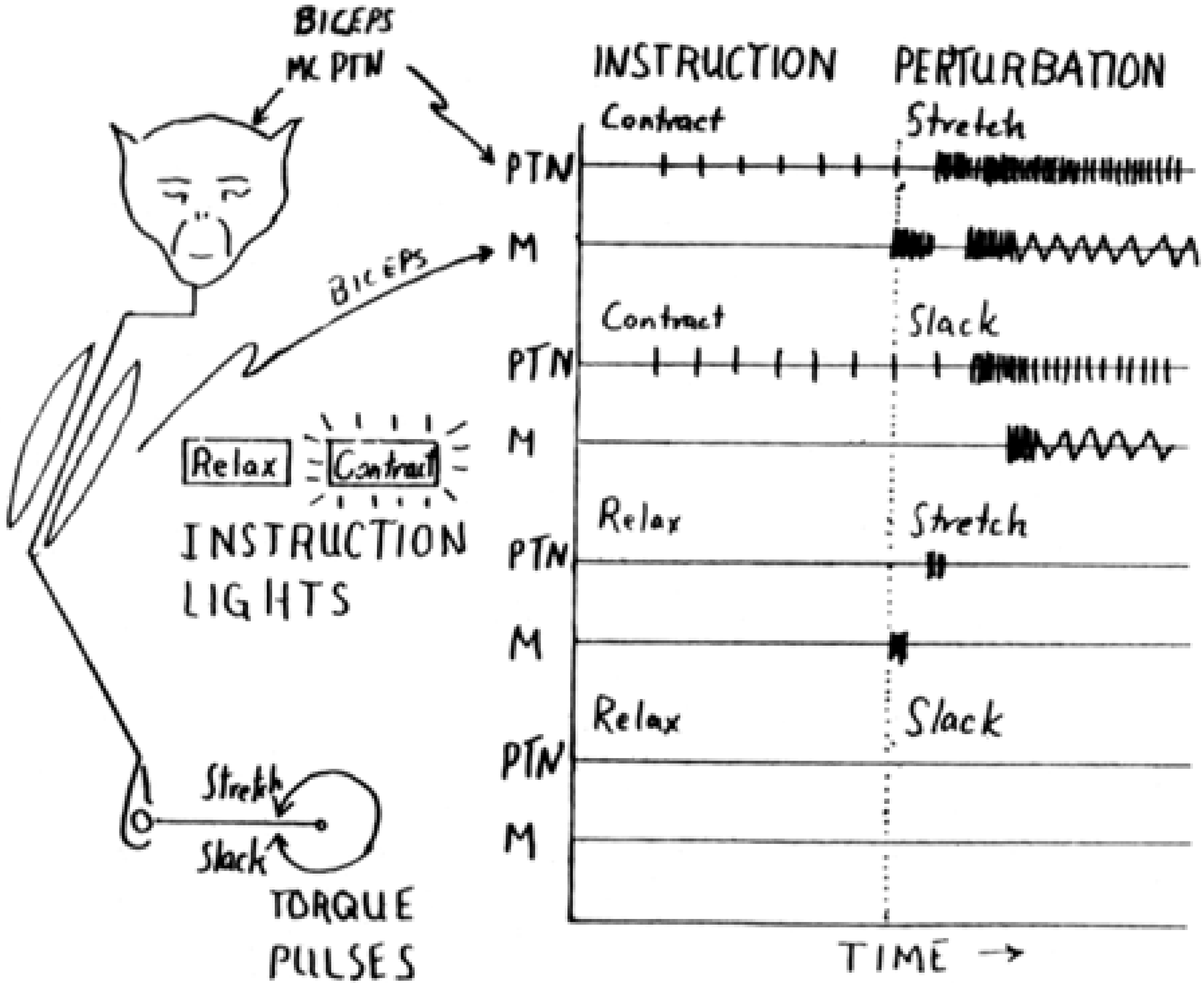
Horizontal connections MA activate distant motor corte neurons (e.g., to hold the forefinger still) while local neurons e.g. cause the 4th finger to flex…

…or is input from the CEREBELLUM that Combines actions of different muscles (to be continued…)

Evidence for transcortical reflex (Evarts)



“Setting” the transcortical reflex (Evarts, Tanji and Evarts)



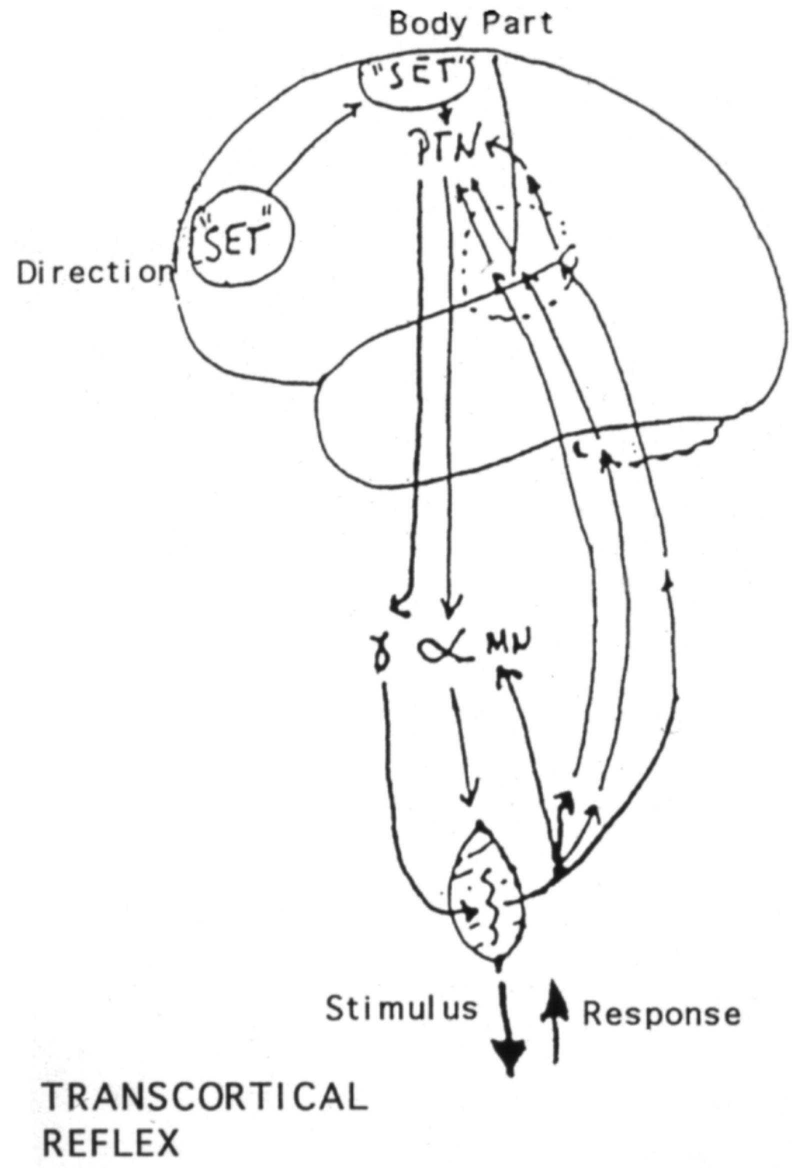


Figure 5.

The "trans-cortical reflex":
Fast, automatic and limited range (like a reflex)
But has to be consciously intended (or "set") like a voluntary movement
Properties:
1.Adequate stimulus is a *STRETCH* of the muscle you want to *CONTRACT*.
2. Motor Cortex PTN's have to be "set" by low frequency firing from SMA (selects which body part is "set" and ultimately from prefrontal cortex (selects direction of response)
3. "Setting" is the mental correlate "willing" the reflex to occur. Since it requires operation of "The Will", it mixes properties of "reflex" and "voluntary" movements

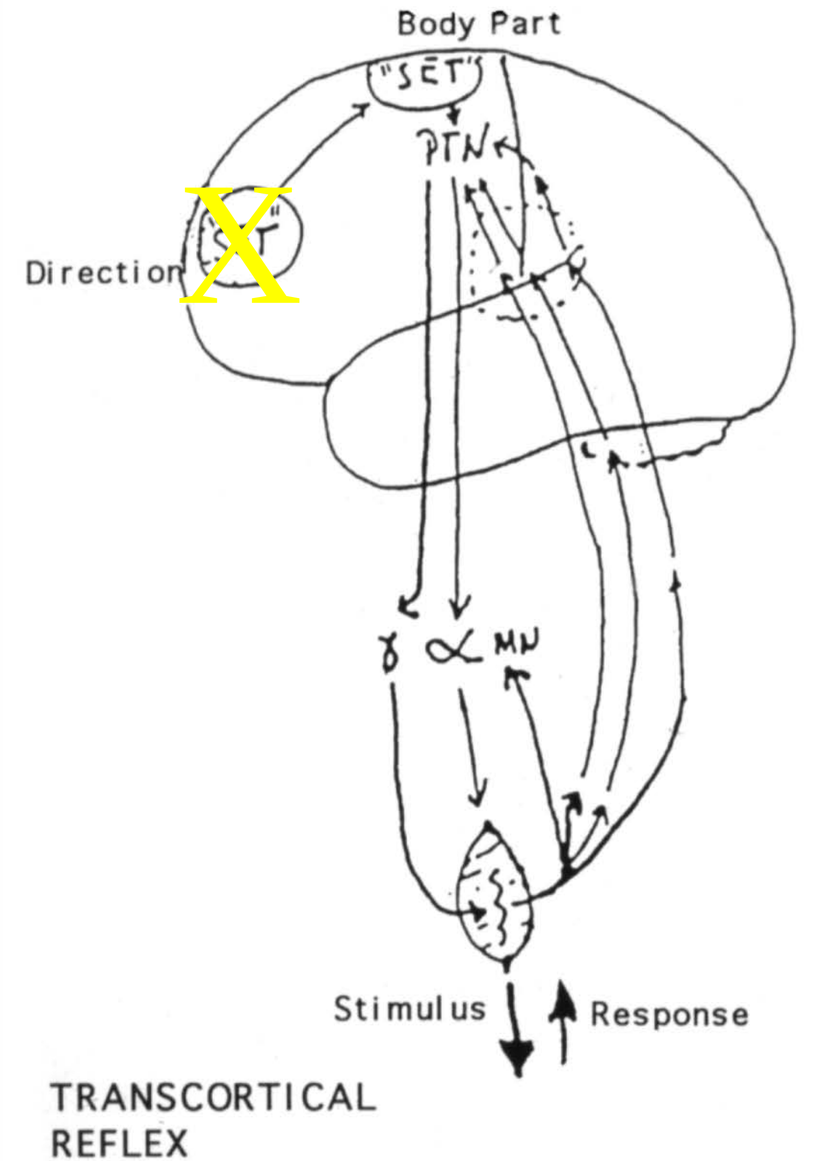


Figure 5.

Cerebral Prefrontal Lesion causes SMA And Motor Cortex to become spontaneously hypersensitive to any remaining input. It is as though the long loop transcortical is "set" all the time, independent of the "Will" of the subject.

Responses consist of the Traction Grasp and Tactile Grasp reflexes, the so called "Pathologic Grasp Reflexes" .

CEREBRAL CORTEX AND THE CONTROL OF VOLUNTARY MOVEMENTS.

Primary motor cortex, area 4, M1

Distal body parts have greater area of cortical representation than proximal body parts.   Distal body parts are under greater cortical control for voluntary movements than proximal body parts.
Specialty: Movement of single digits.

Secondary Motor Cortical areas--SMA, PMC, PFC: high level planni of movements; thinking about movements without actually making them.
Parietal: targeting movements to objects in extrapersonal space.

Transcortical reflexes: spindle, tactile