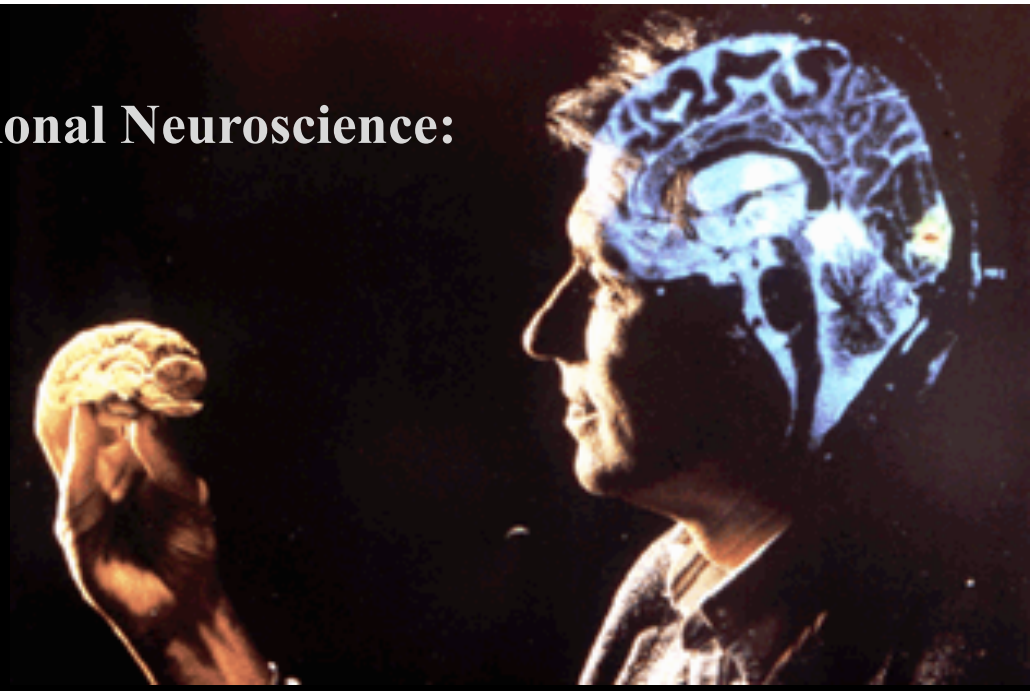
Introduction to Systems and Computational Neuroscience: Tactile Perception



LESSON 2.
MAPS

REVIEW
for MsPCS students

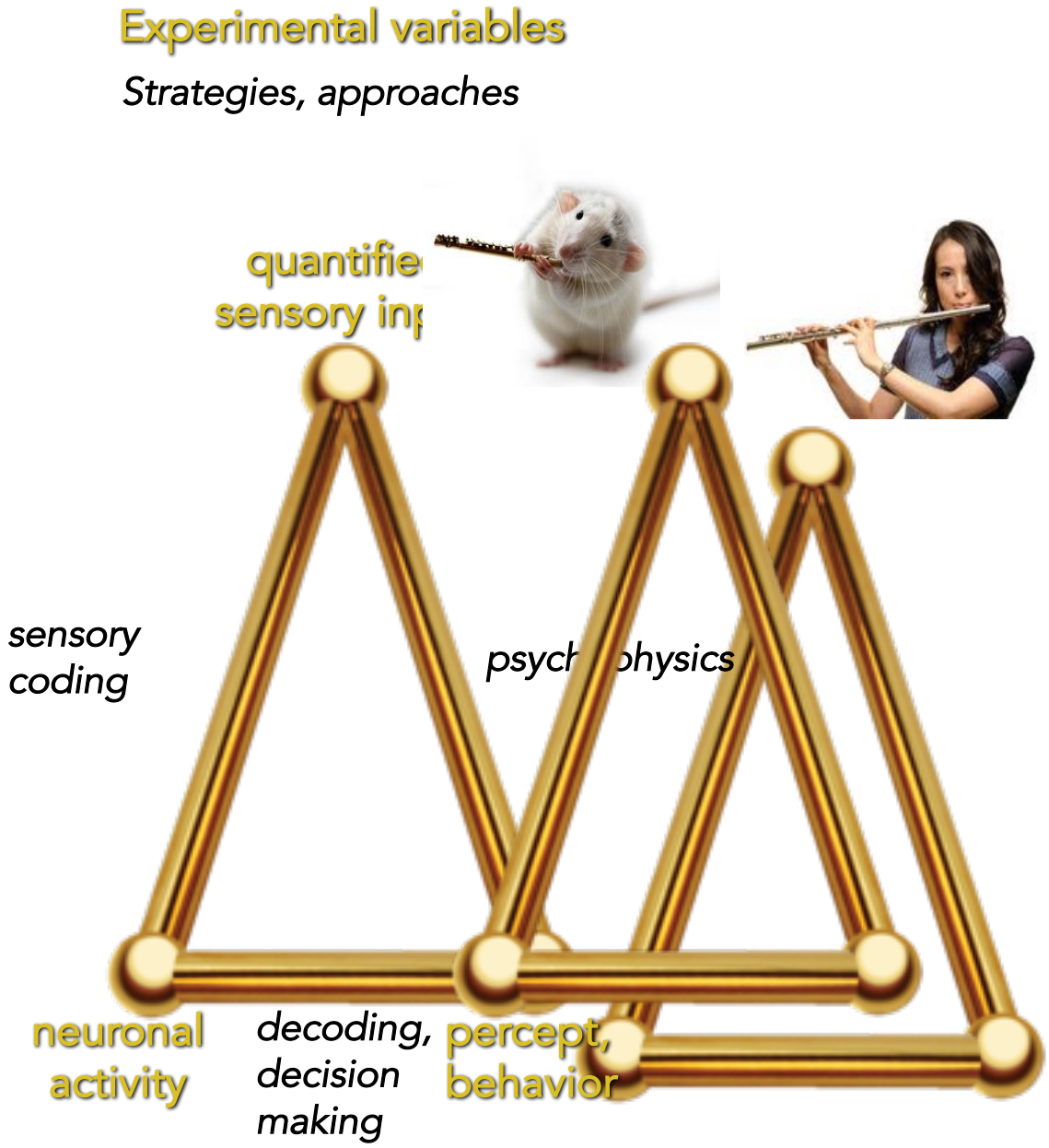
intelligence

We are intelligent enough to understand our own intelligence

curiousity

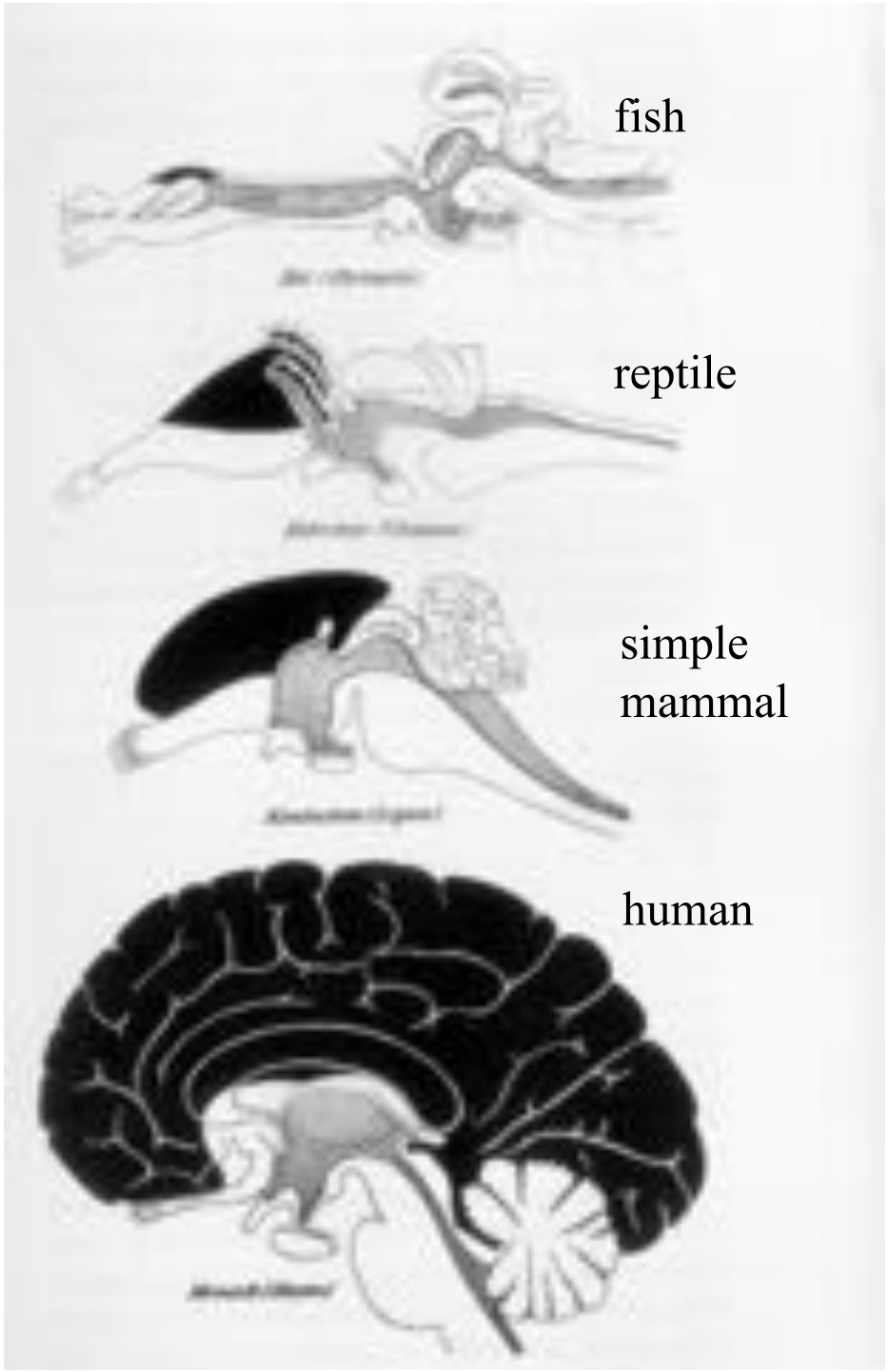
We just don't care

How can we go about studying the neuronal processes involved in sensation and perception?



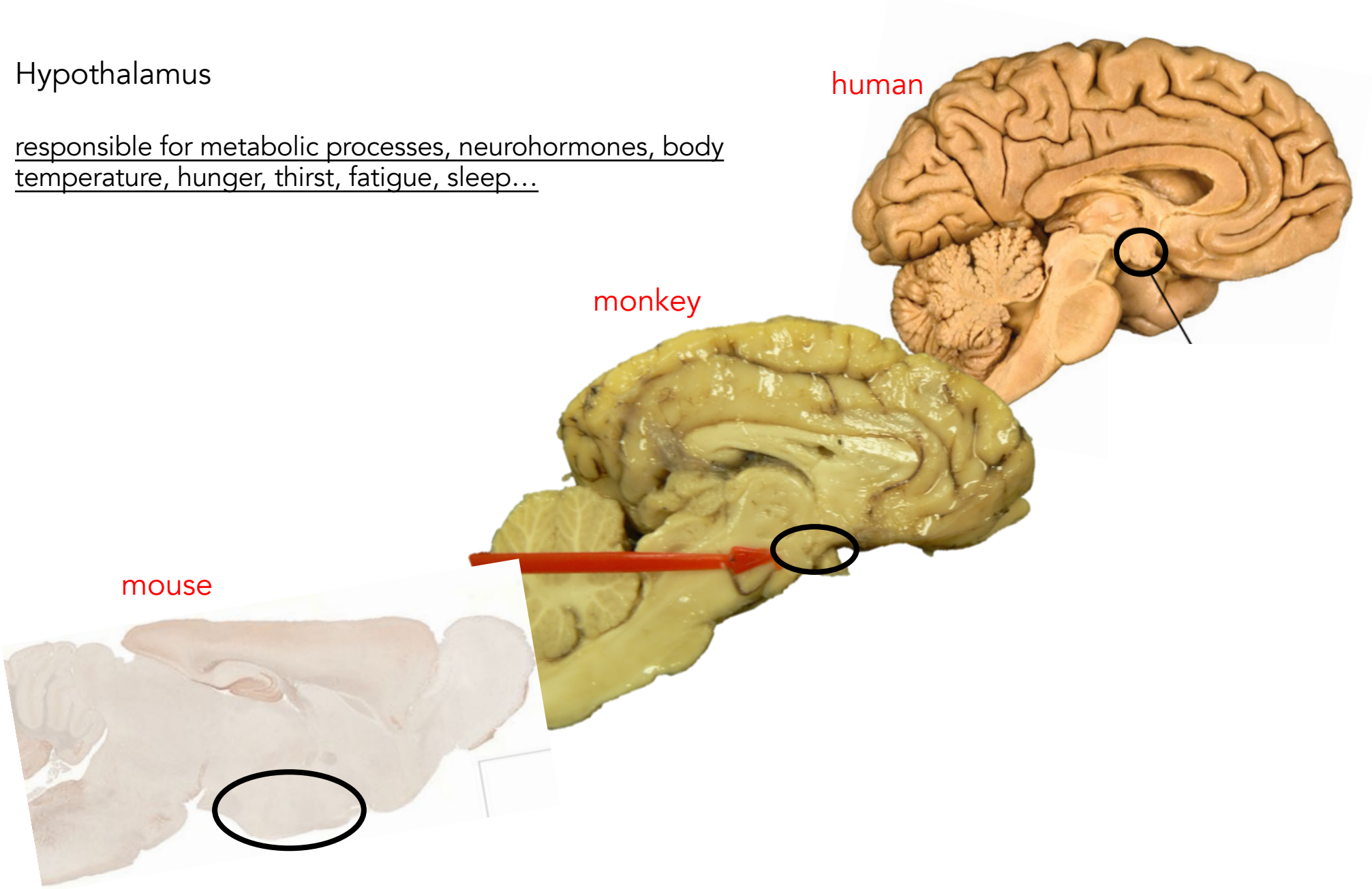
Cerebral cortical evolution:
cerebral cortex / whole brain increases

See Treves lectures



Hypothalamus

responsible for metabolic processes, neurohormones, body temperature, hunger, thirst, fatigue, sleep…



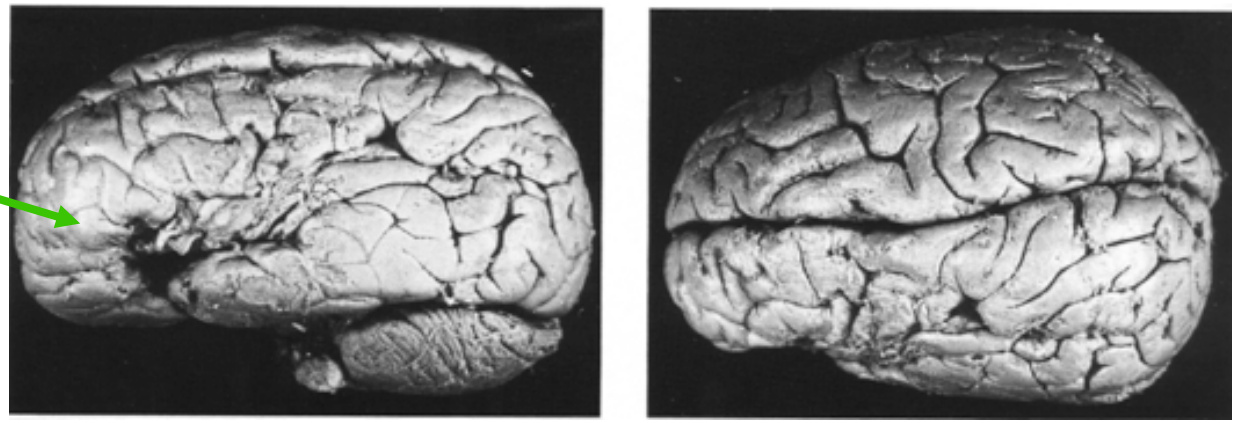
(brain images rescaled to similar size for illustration)

Localization of function

Localization of function by lesion
(neuropsychology)

1861
Broca's patient, "Tan"

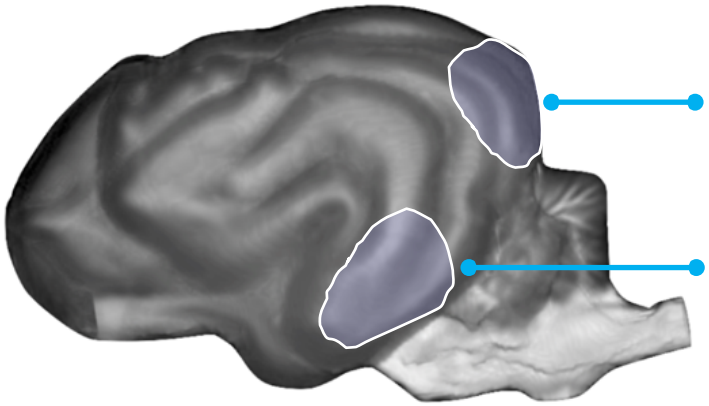
Broca's area



Localized region for language production

Destruction of area produces behavioral deficit

Hermann Munk (1878)
"Ueber die Funktionen der Grosshirnrinde"
"On the functions of the cerebral cortex"



blindness; stumbling into objects

vision conserved; loss of "visual memory" (agnosia)

Ian Whitfield (1979)
"The Object of Sensory Cortex"

- based on 100 yrs of neuroscience -- after ablation of sensory and association regions of cerebral cortex, animals can still perform many forms of sensory discrimination.

- cortical ablation → deficit whenever behavioral task requires the elemental sensory signals to assume meaning according to previous experience.

- intracortical processing transforms mere physical data into the perception of things that are "out there" (Whitfield, p. 146) in the world.

more on Whitfield later in course

Tatsuji Inouye, 1905

perspectives

Tatsuji Inouye and the mapping of the visual fields on the human cerebral cortex

Mitchell Glickstein and David Whitteridge

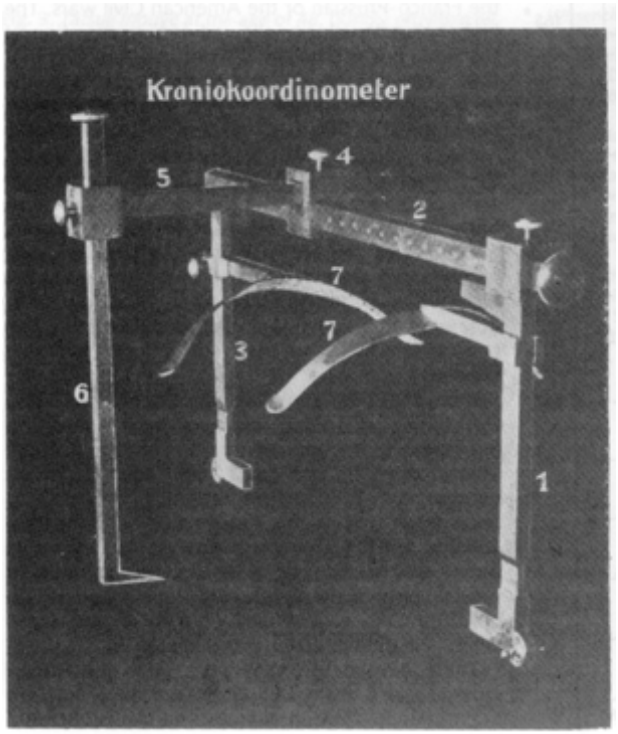

Kraniokoordinometer
1
2
3
4
5
6
7
7

Fig. 2.
Inouye's schema for the projection of the visual fields on the striate cortex.

cortex is devoted to the representation of the centre of the visual field than to the periphery. Some years later, Talbot and Marshal[10] coined the term 'magnification factor' to mean the extent of visual cortex in millimeters that represents one degree of the visual field. Magnification is high in the centre of gaze, and

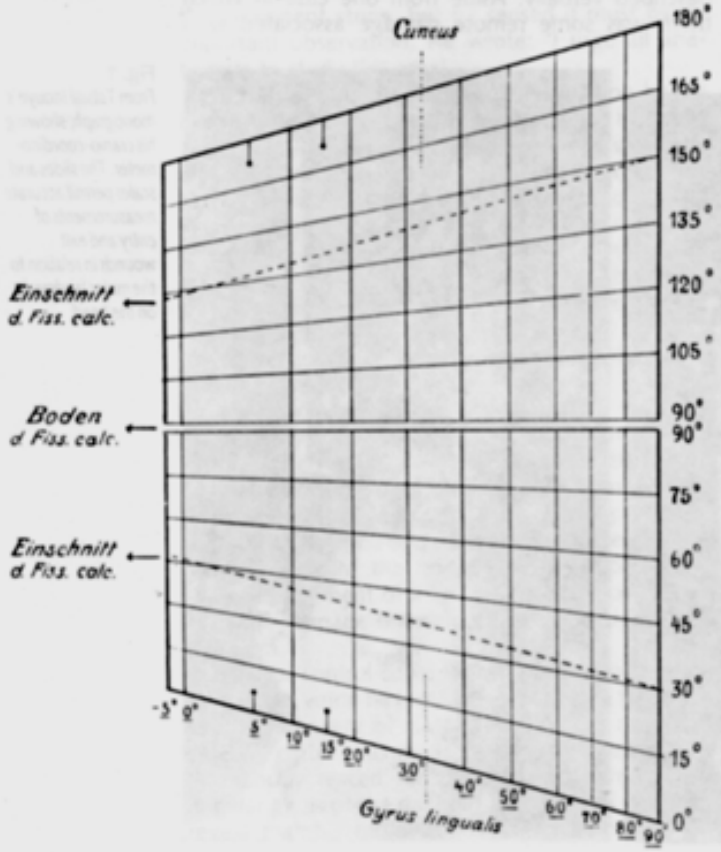
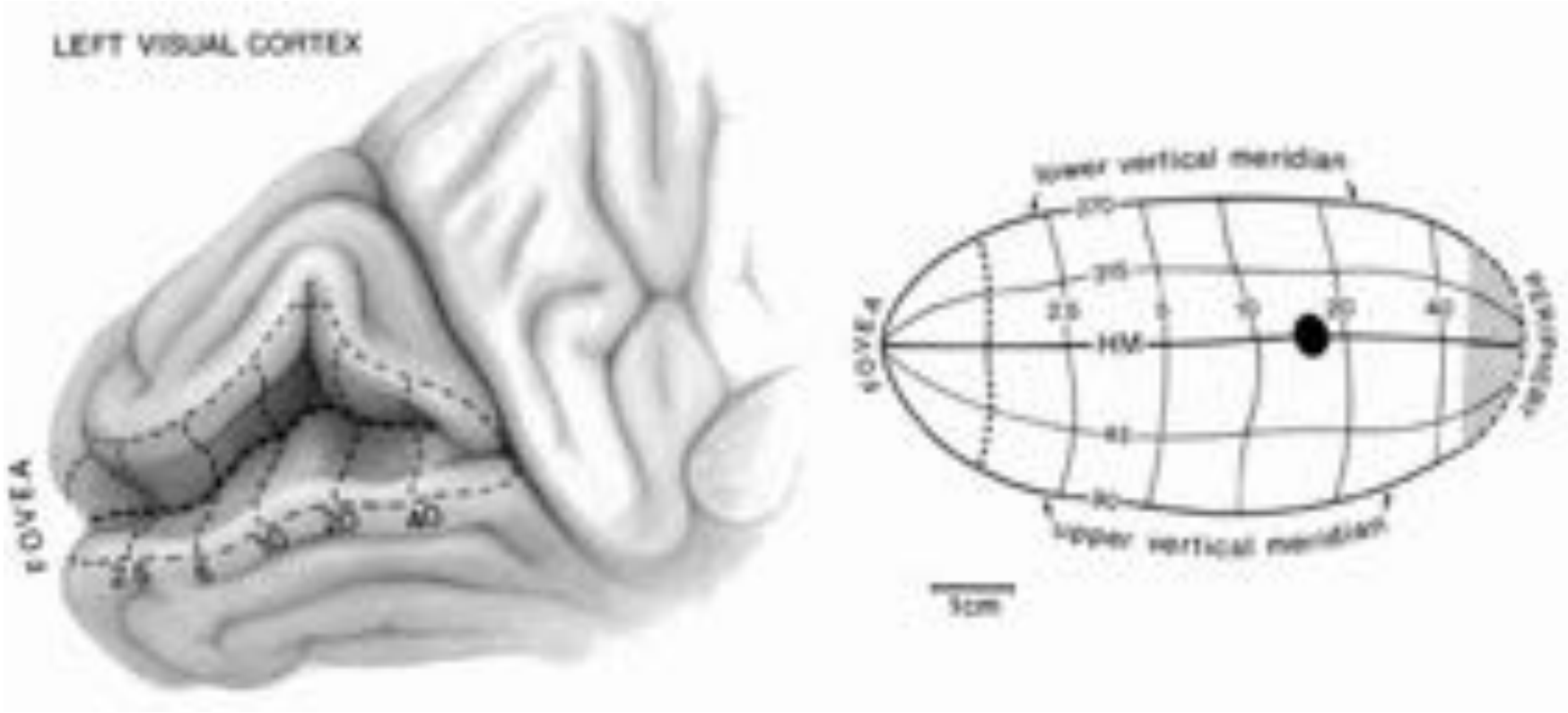


Fig. 2.
Inouye's schema for the projection of the visual fields on the striate cortex.

human visual cortex retinal map by modern methods

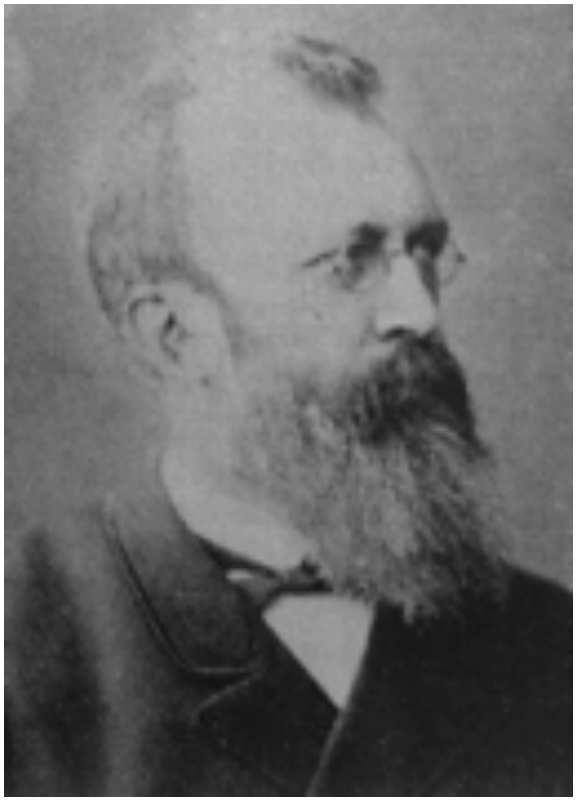


Localization of function

Localization of function by electrical
electrical recording and stimulation

(neurophysiology and neurosurgery)

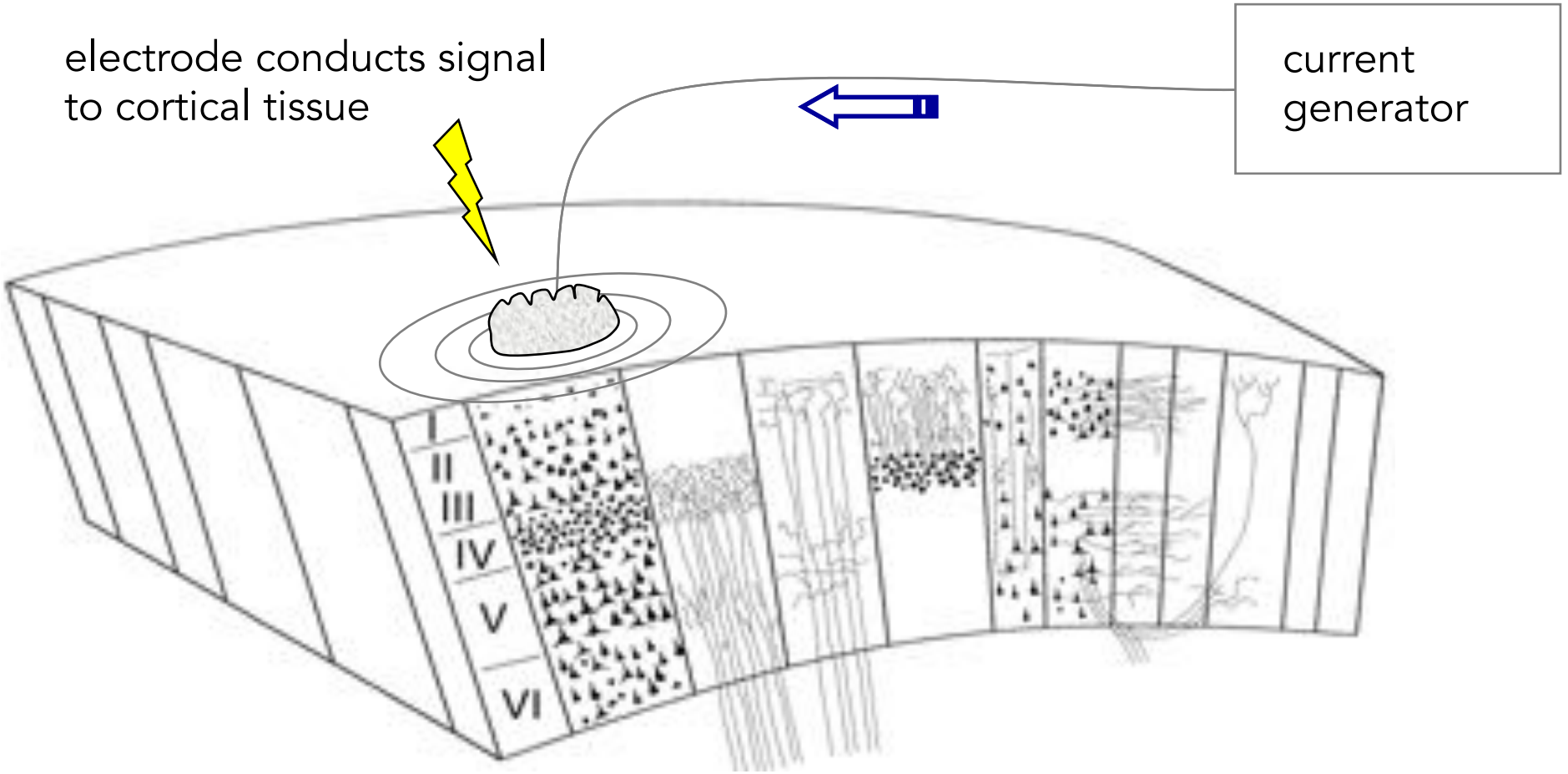
the method of targeted and
restricted electrical stimulation...



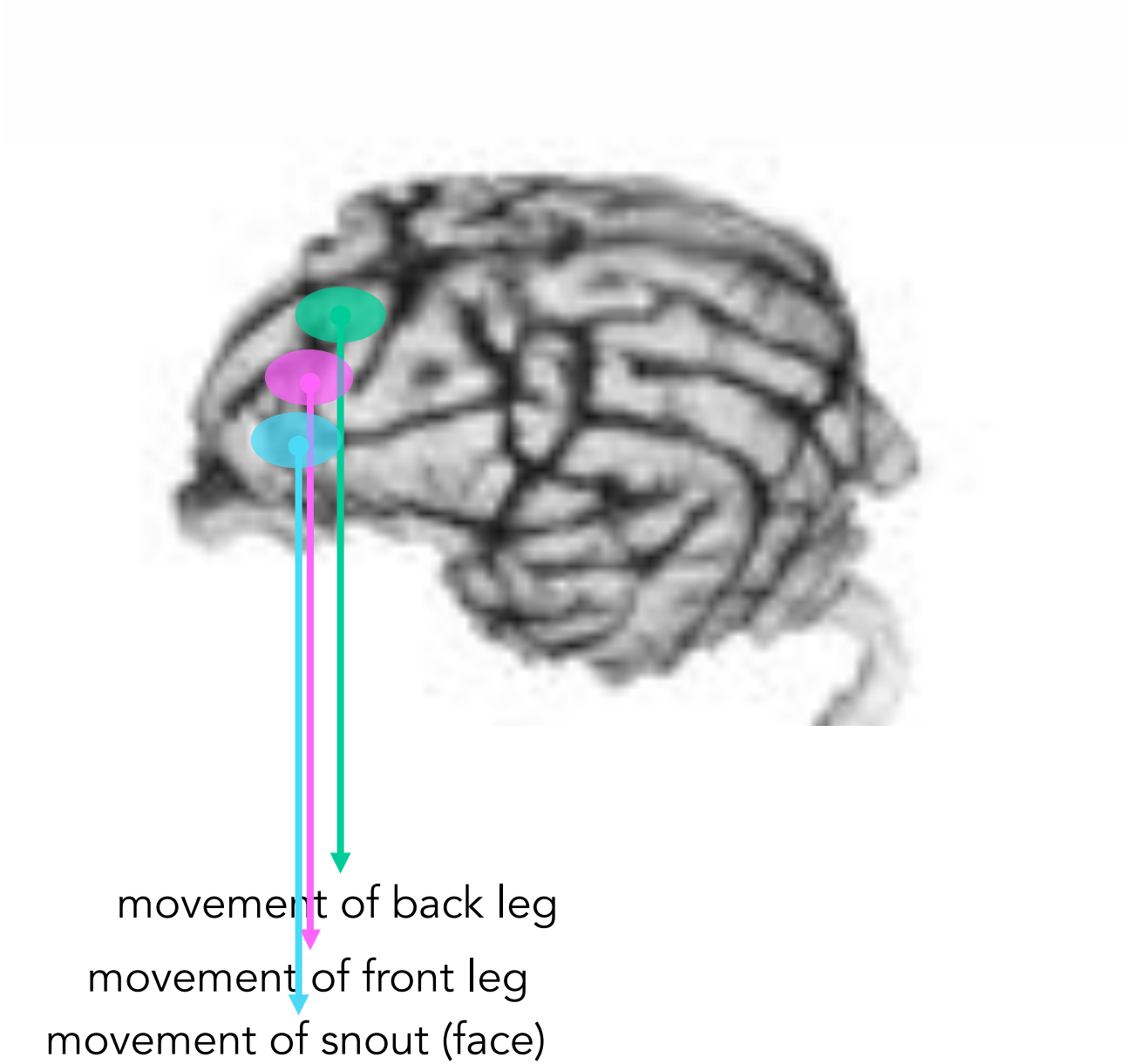
Hitzig

Fritsch

electrical stimulus

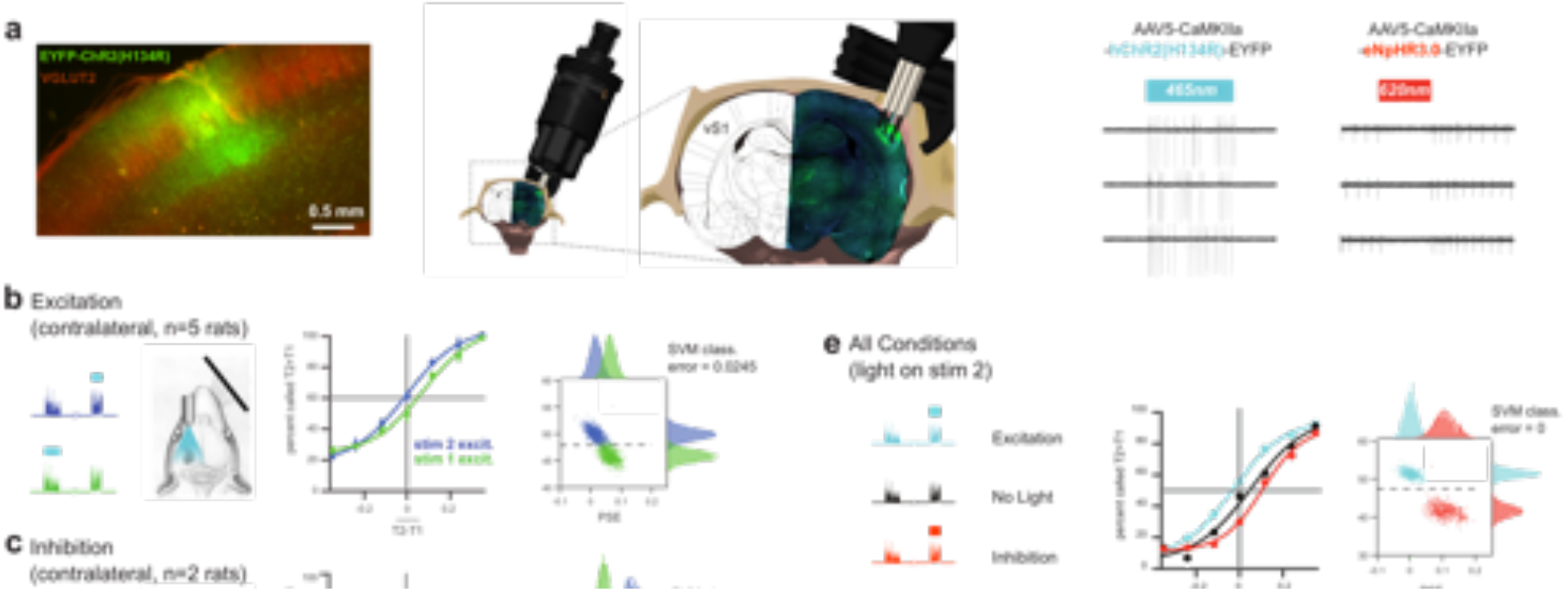


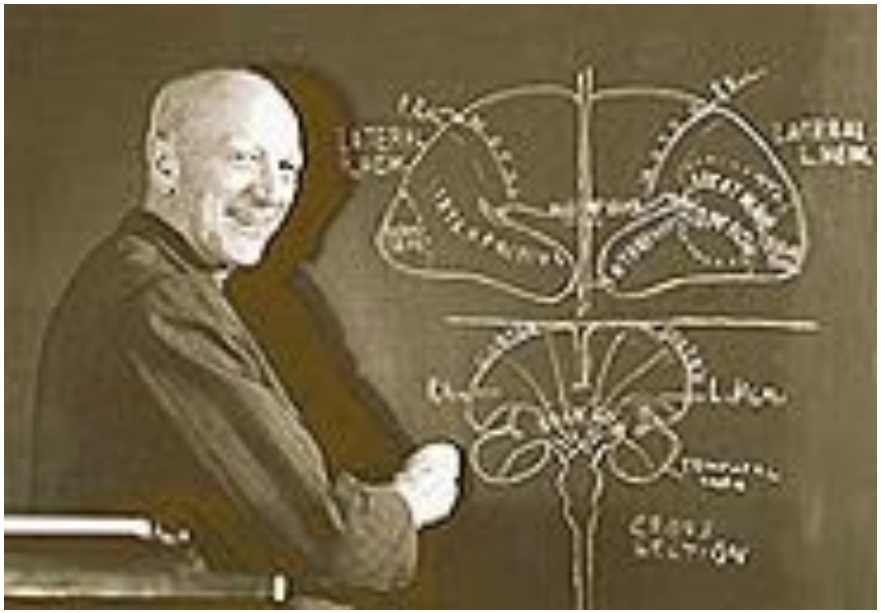
…led to the detection of areas with specific motor functions



Today's methods

Sebastian Reinartz
SISSA postdoc





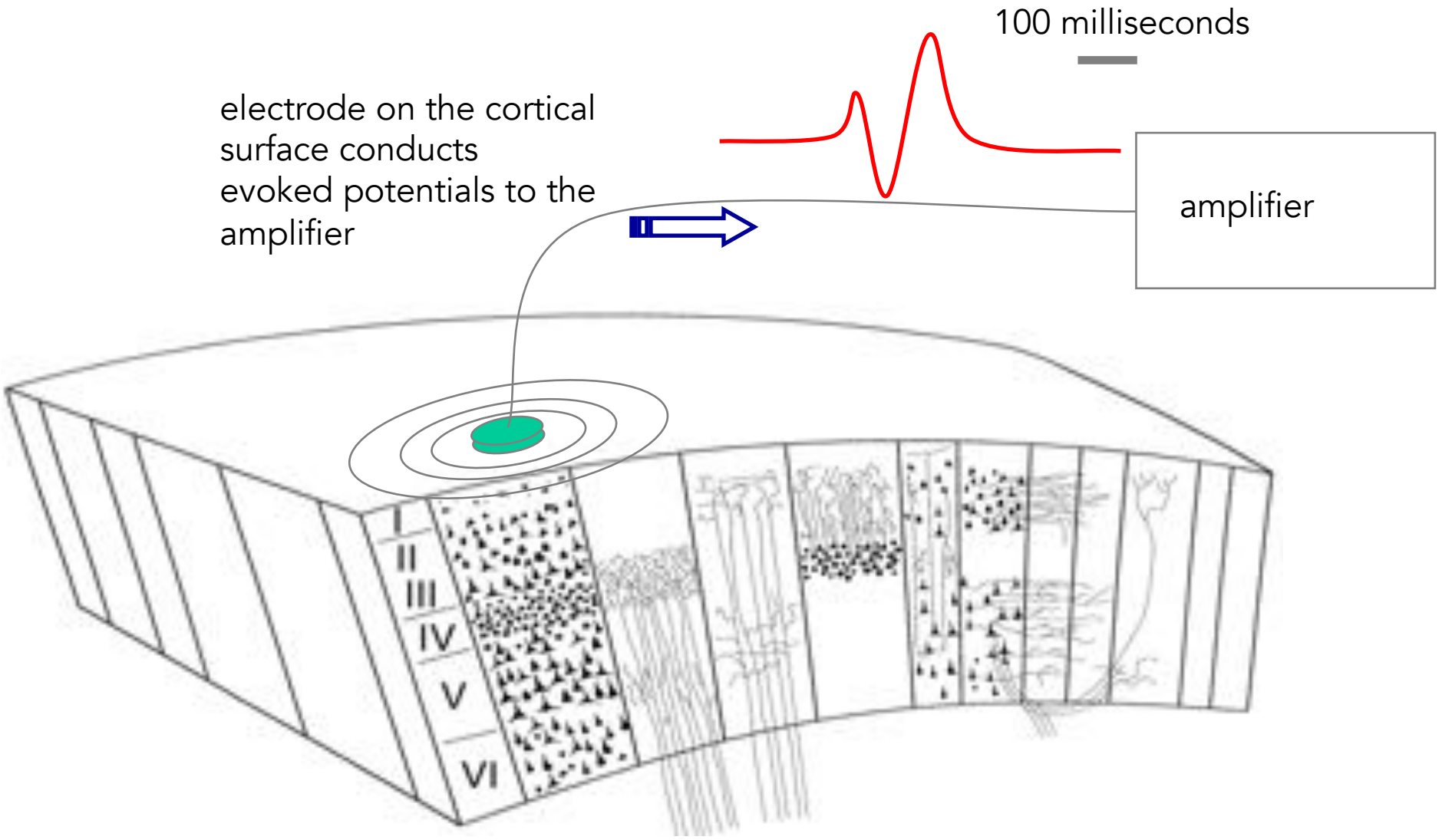
Wilder Penfield

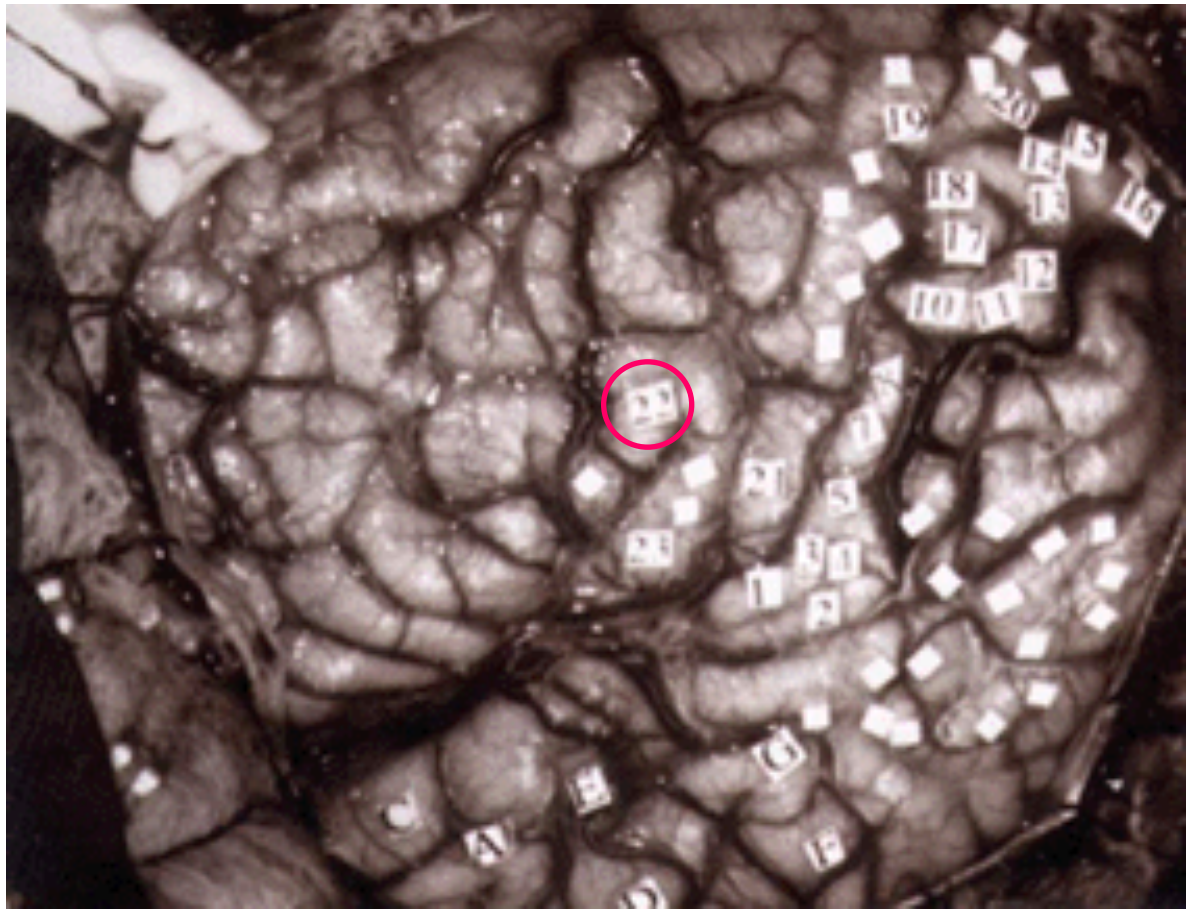
physiological exploration of the human cerebral cortex

(c. 1930-1970)

Epilepsy and the Functional Anatomy of the Human Brain. 2nd edition.
Jasper, H., and Penfield, W. Little, Brown and Co., 1954.

“evoked potentials“
a probe of the activity of neuronal populations

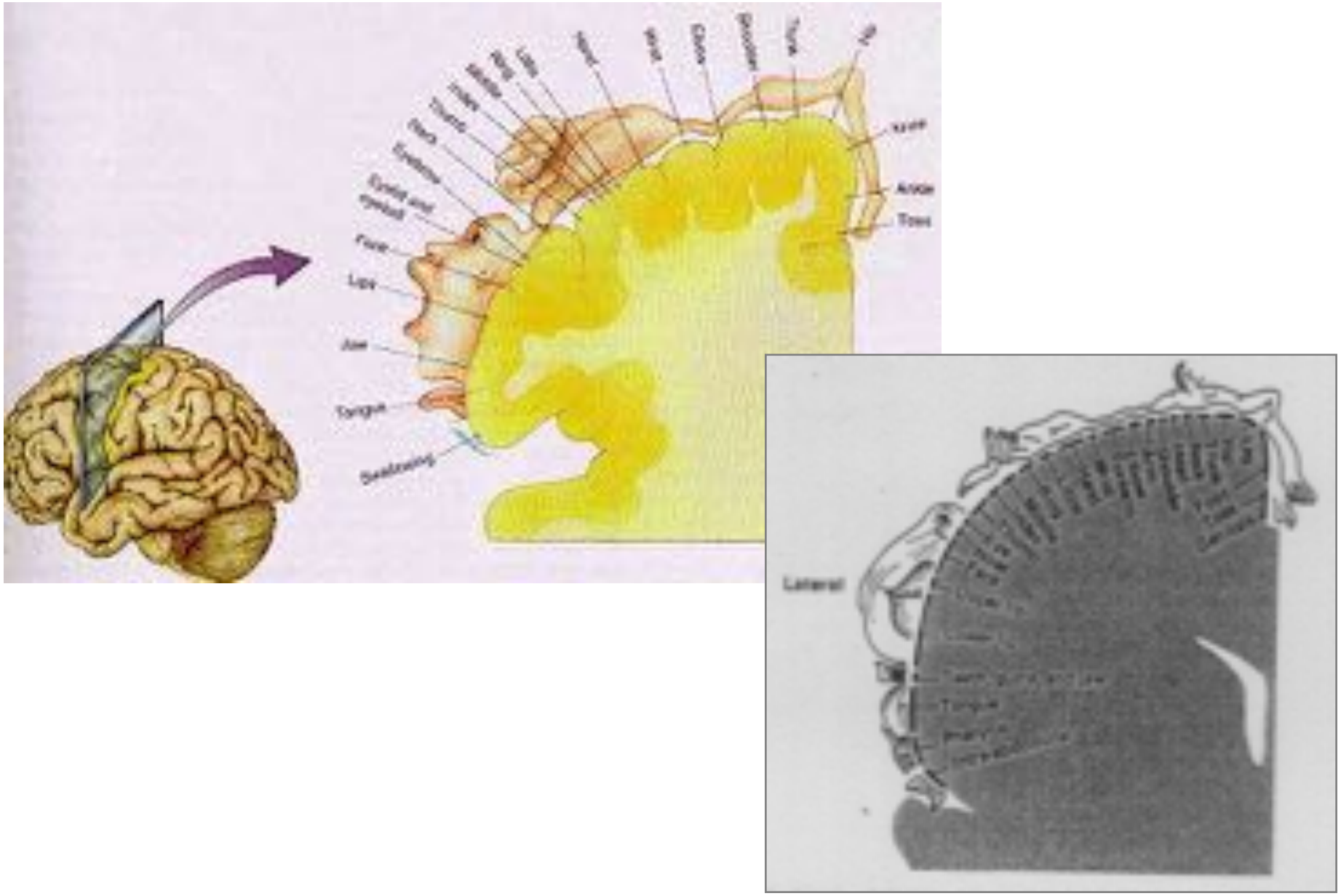


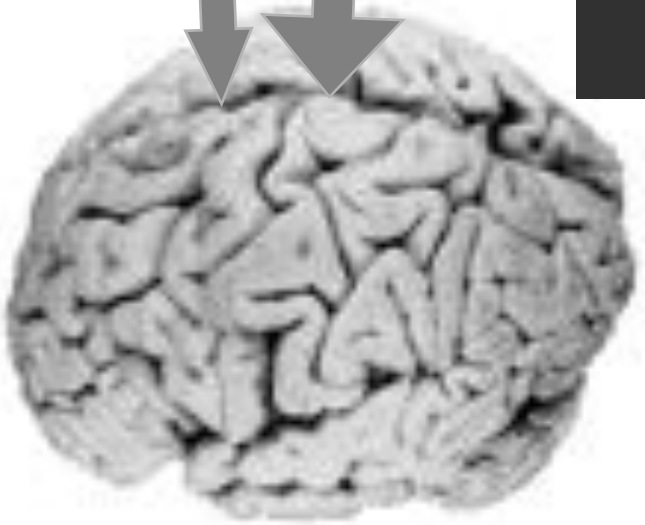


https://www.youtube.com/watch?v=obiARnsKUAo

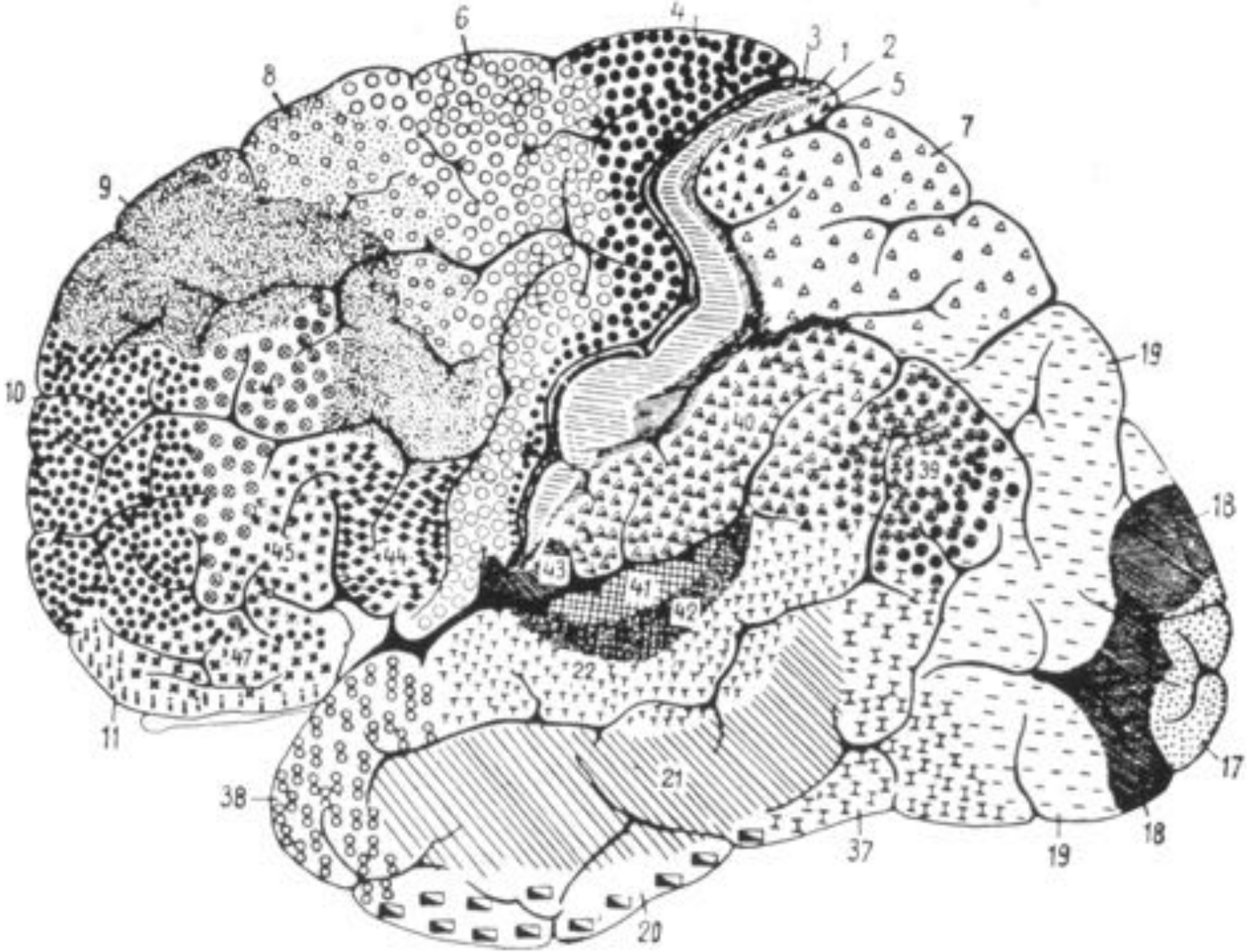
2:40 --Singing interrupted by cortical stimulation

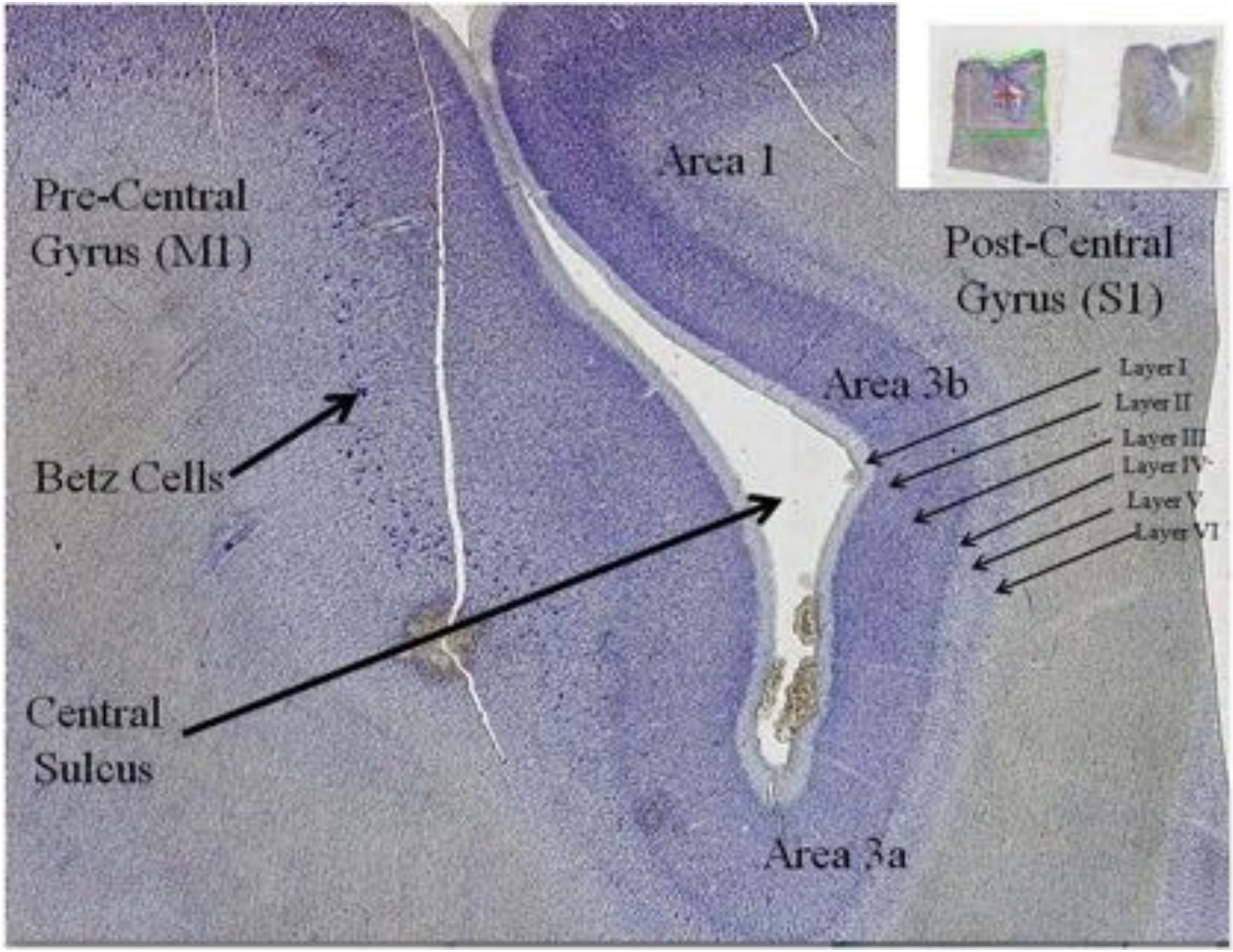
the motor and the sensory maps in the human





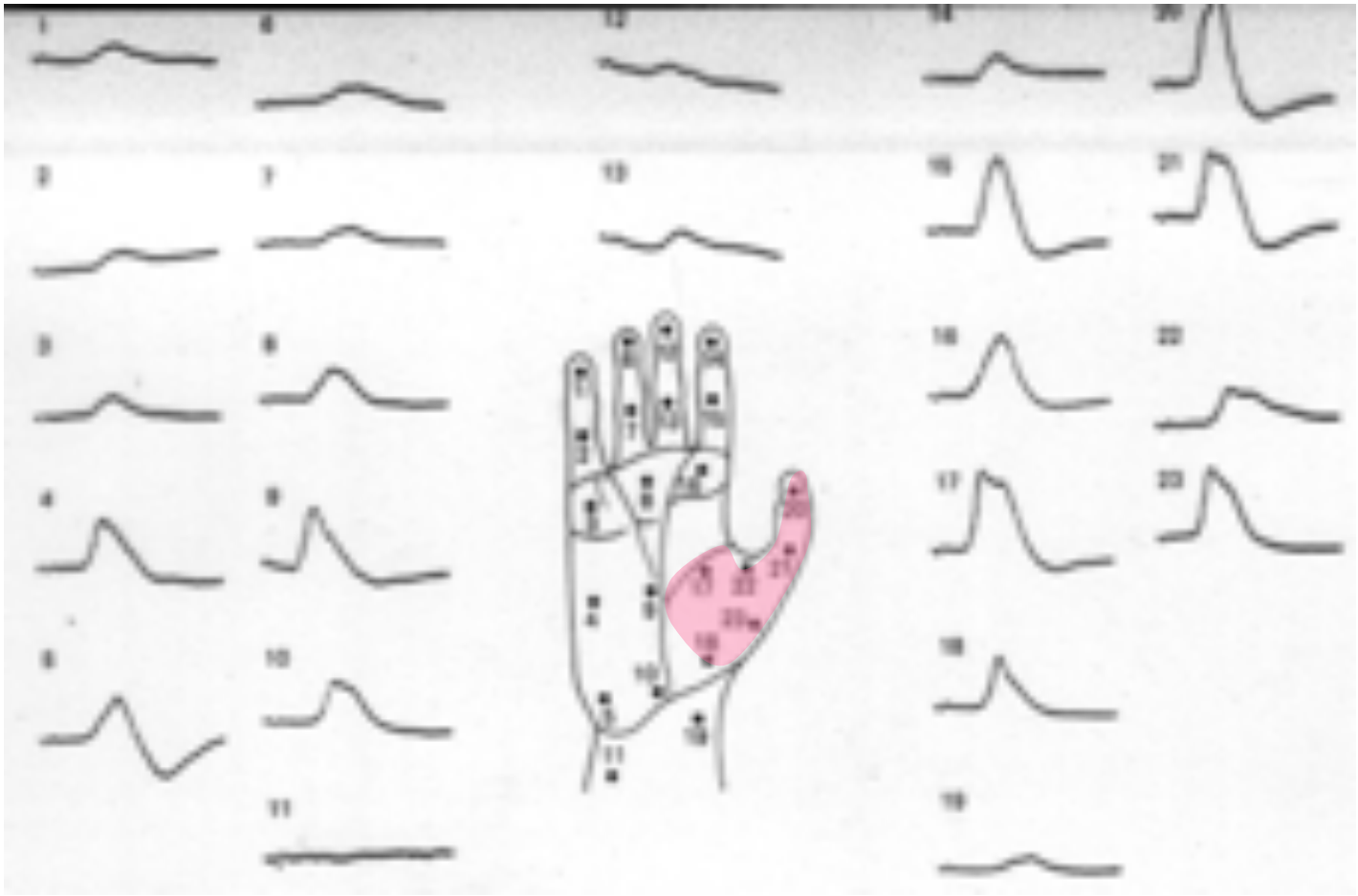
Human


6
4
3
1
2
5
8
7
9
10
19
40
39
18
45
44
43
41
42
22
47
11
21
38
37
19
18
17
20

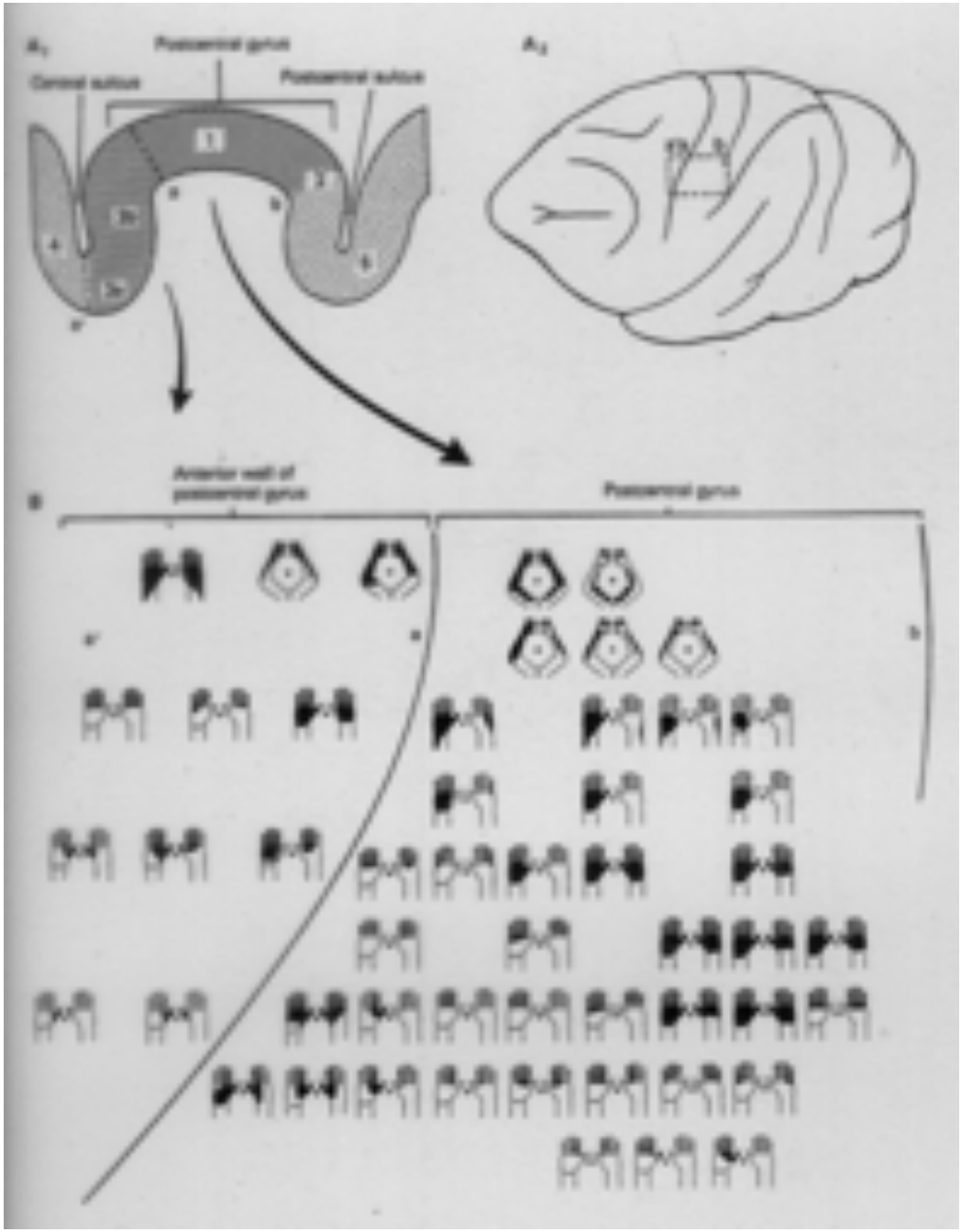

Pre-Central
Gyrus (M1)
Area 1
Post-Central
Gyrus (S1)
Area 3b
Layer I
Layer II
Layer III
Layer IV
Layer V
Layer VI
Betz Cells
Central
Sulcus
Area 3a

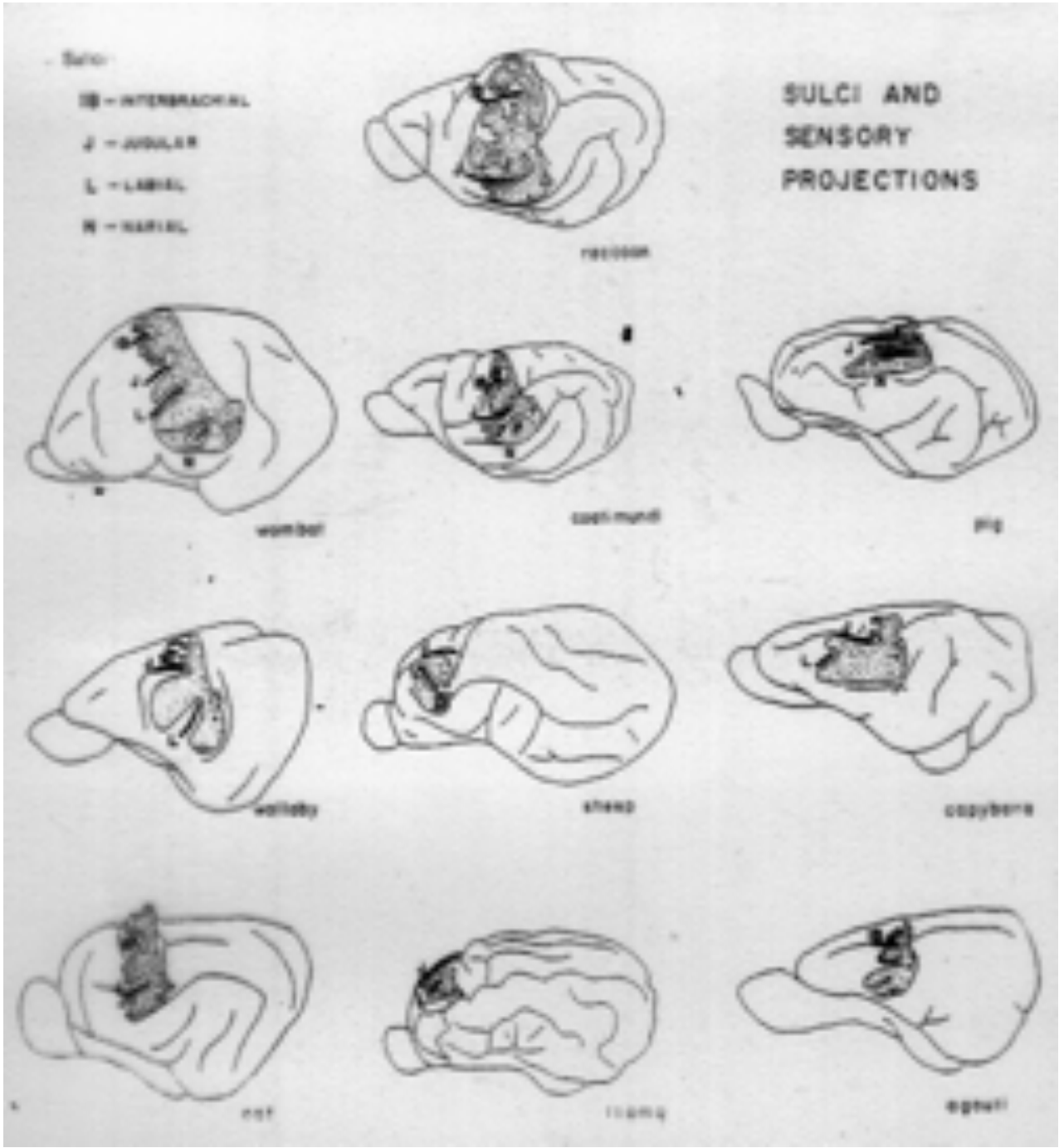
Clinton Woolsey
University of Wisconsin

*What is the **receptive field** for this cortical site?*

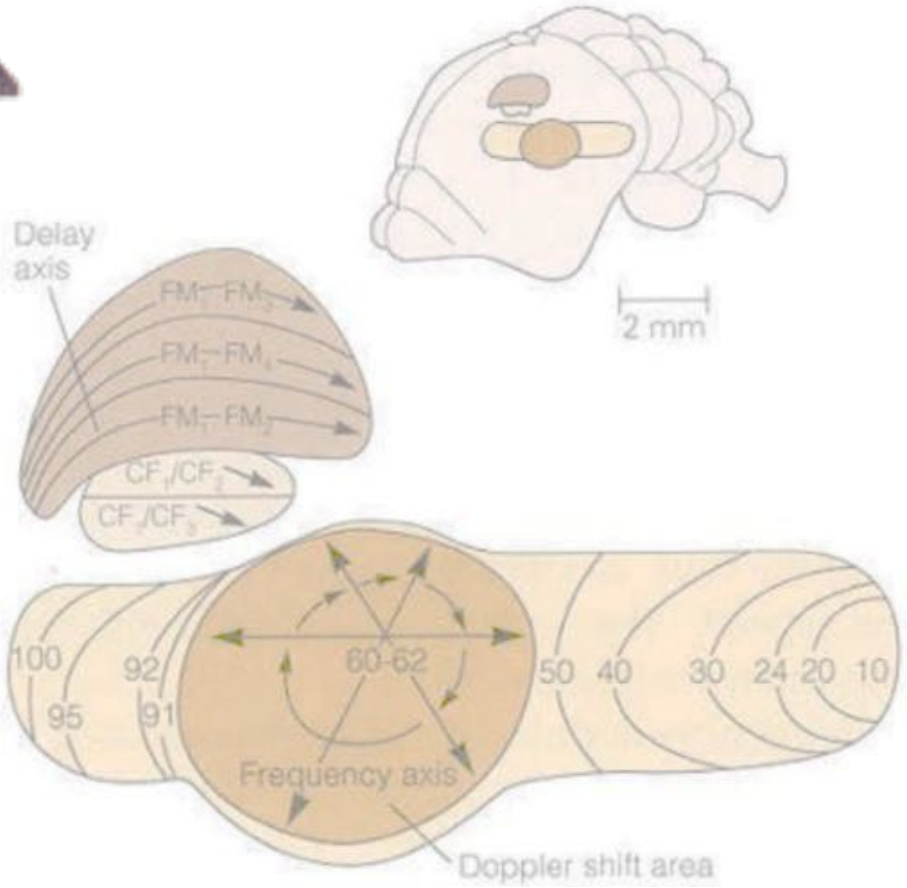


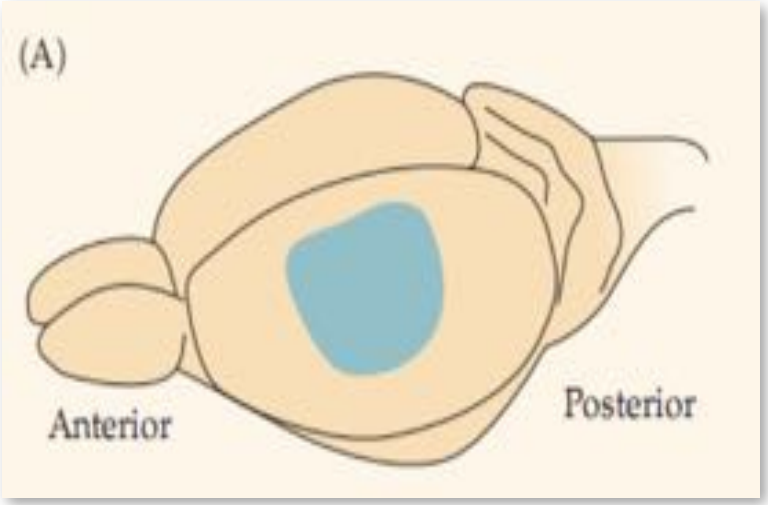
Woolsey's evoked potential mapping:
the skin area projecting to a single cortical site

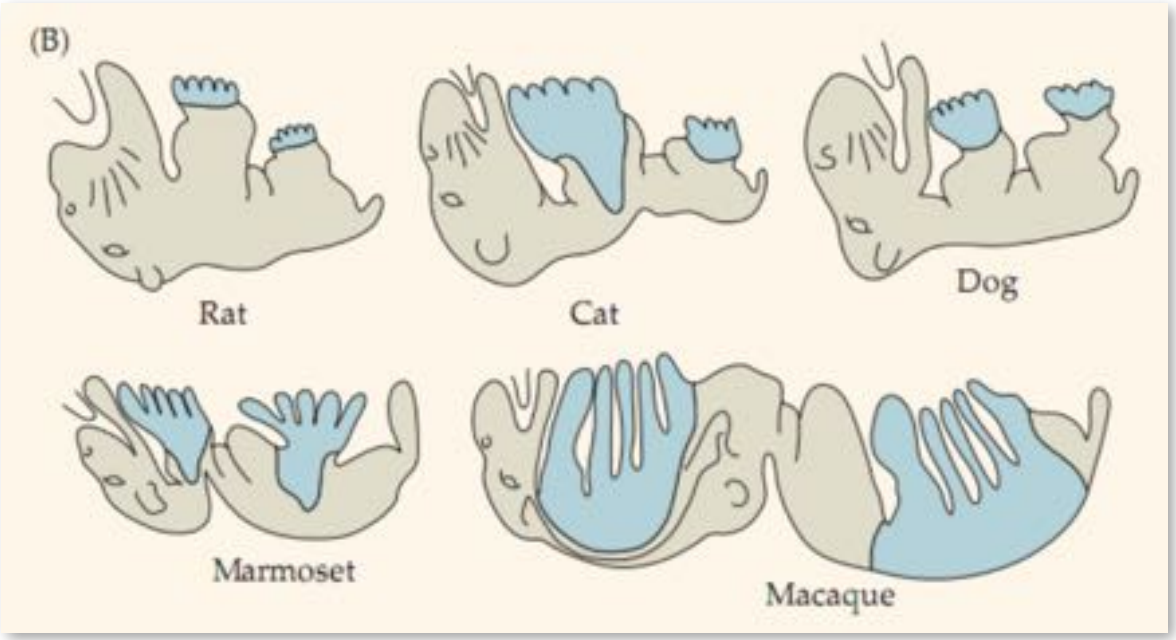

A1
Postcentral gyrus
Central sulcus
Postcentral sulcus
A2
B
Anterior wall of postcentral gyrus
Postcentral gyrus


SULCI AND
SENSORY
PROJECTIONS

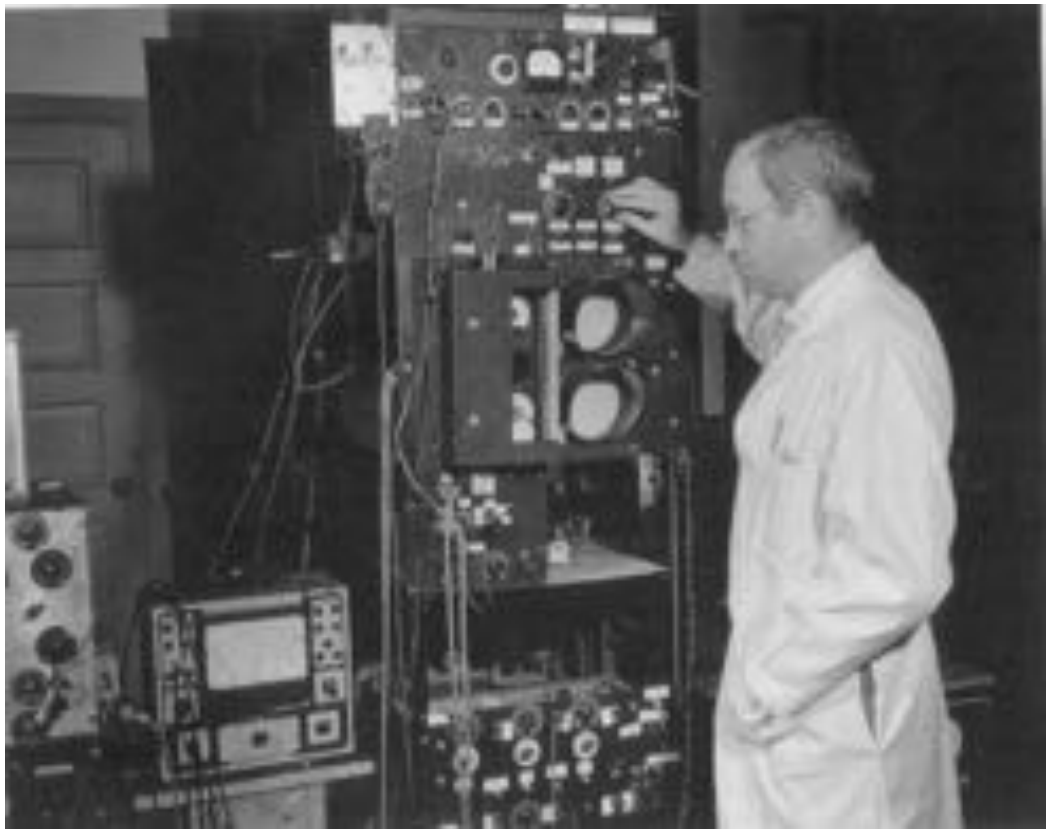
bat auditory cortex





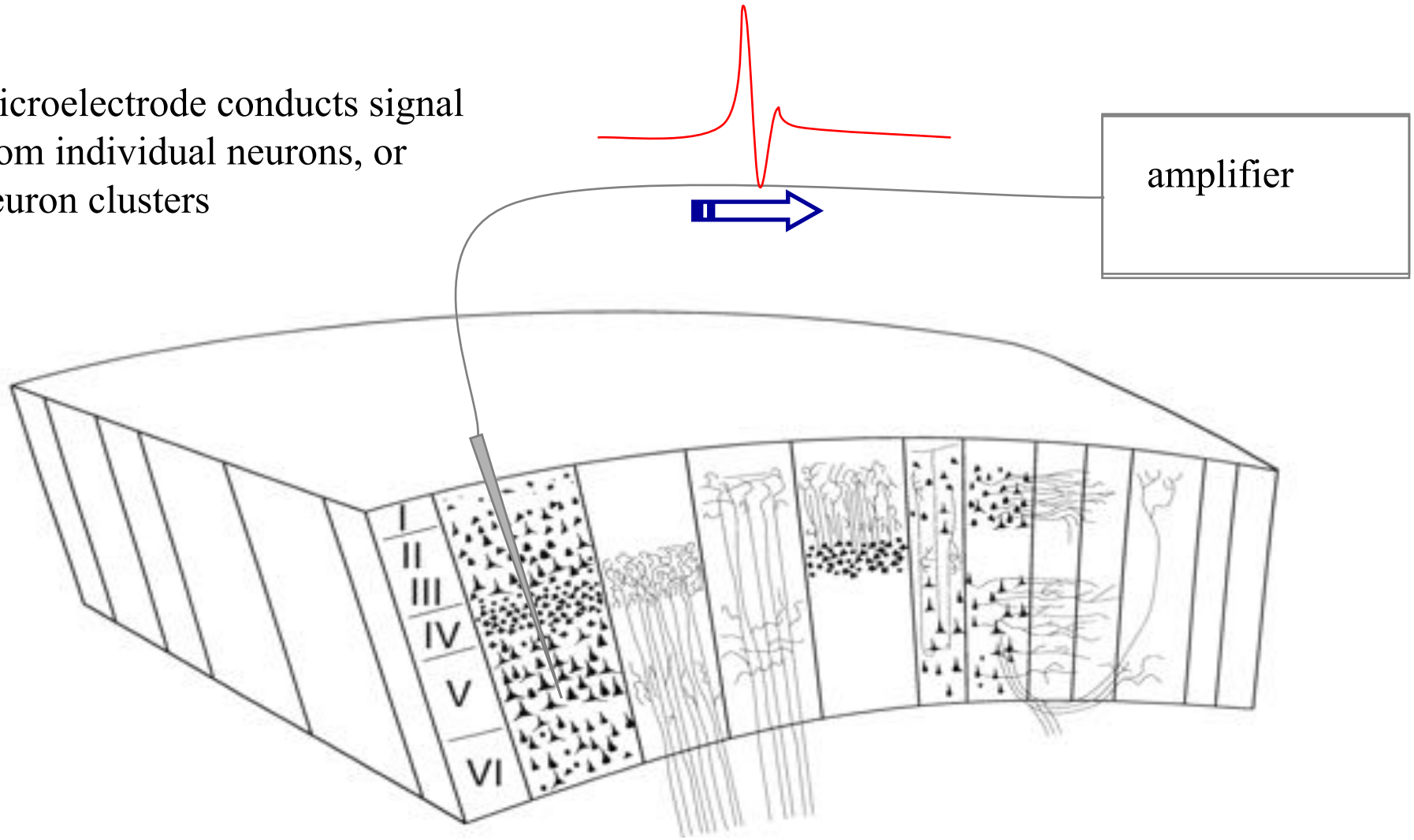


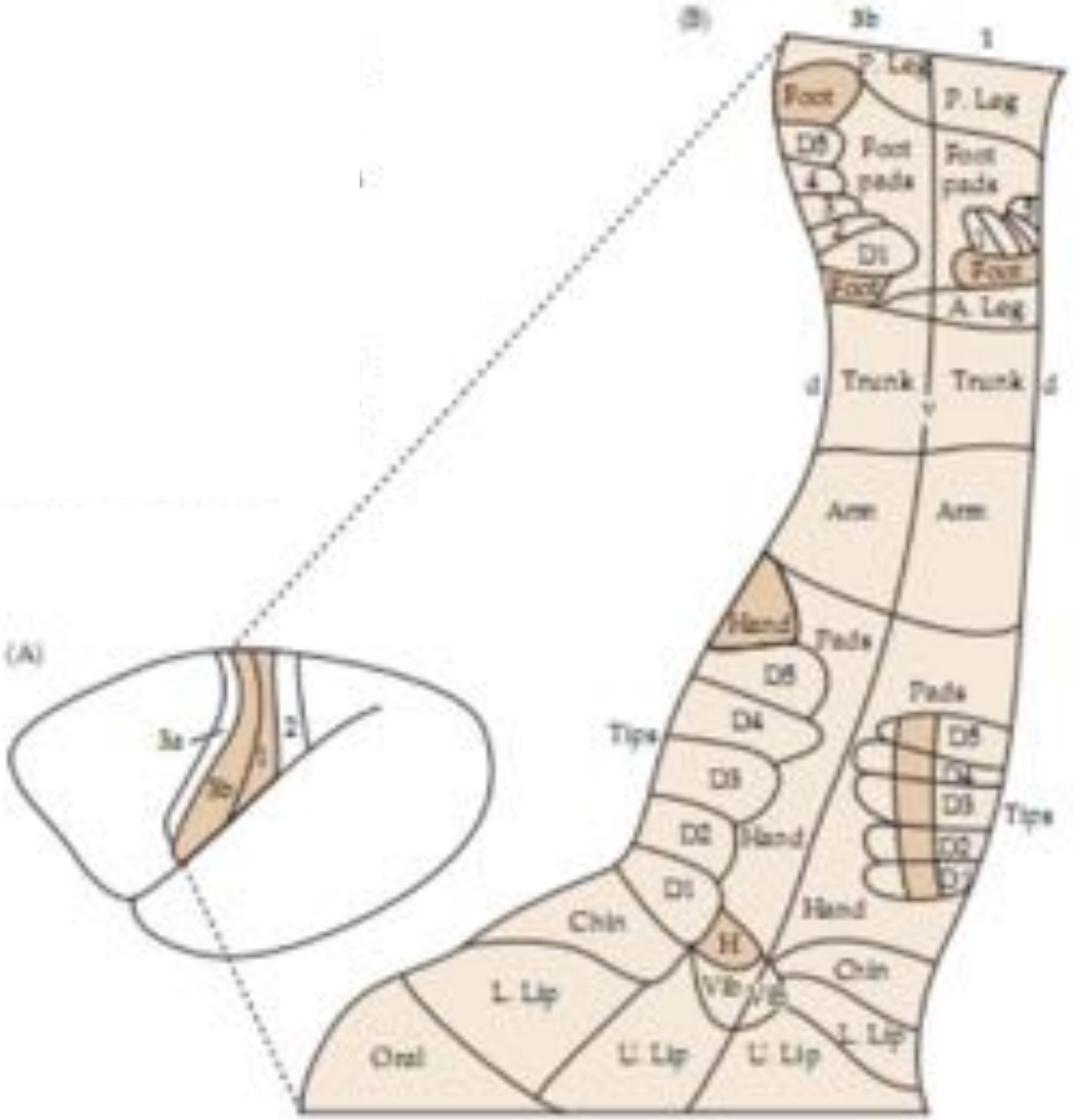
- expansion of the most valuable sensory modality
- expansion of the most valuable receptors within a given representation

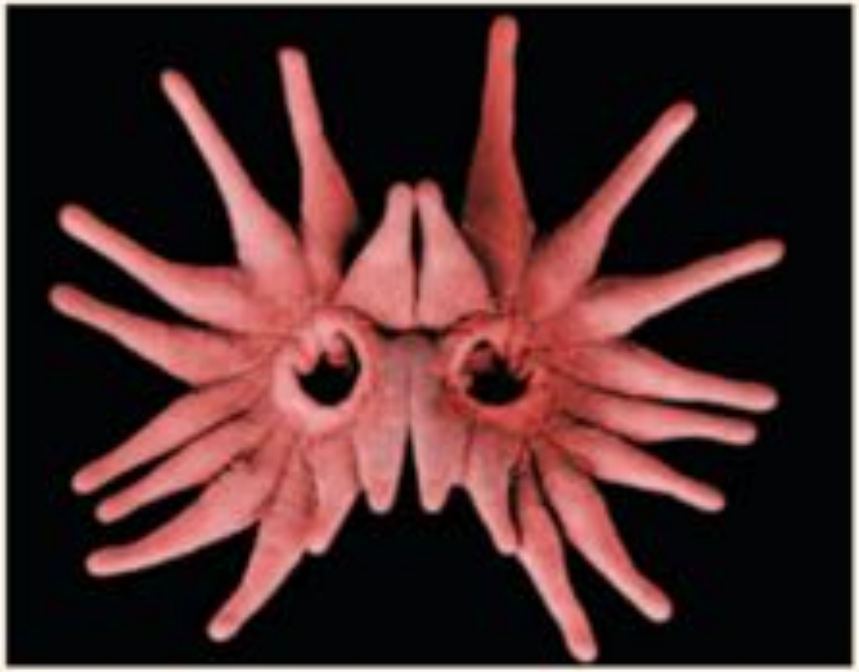


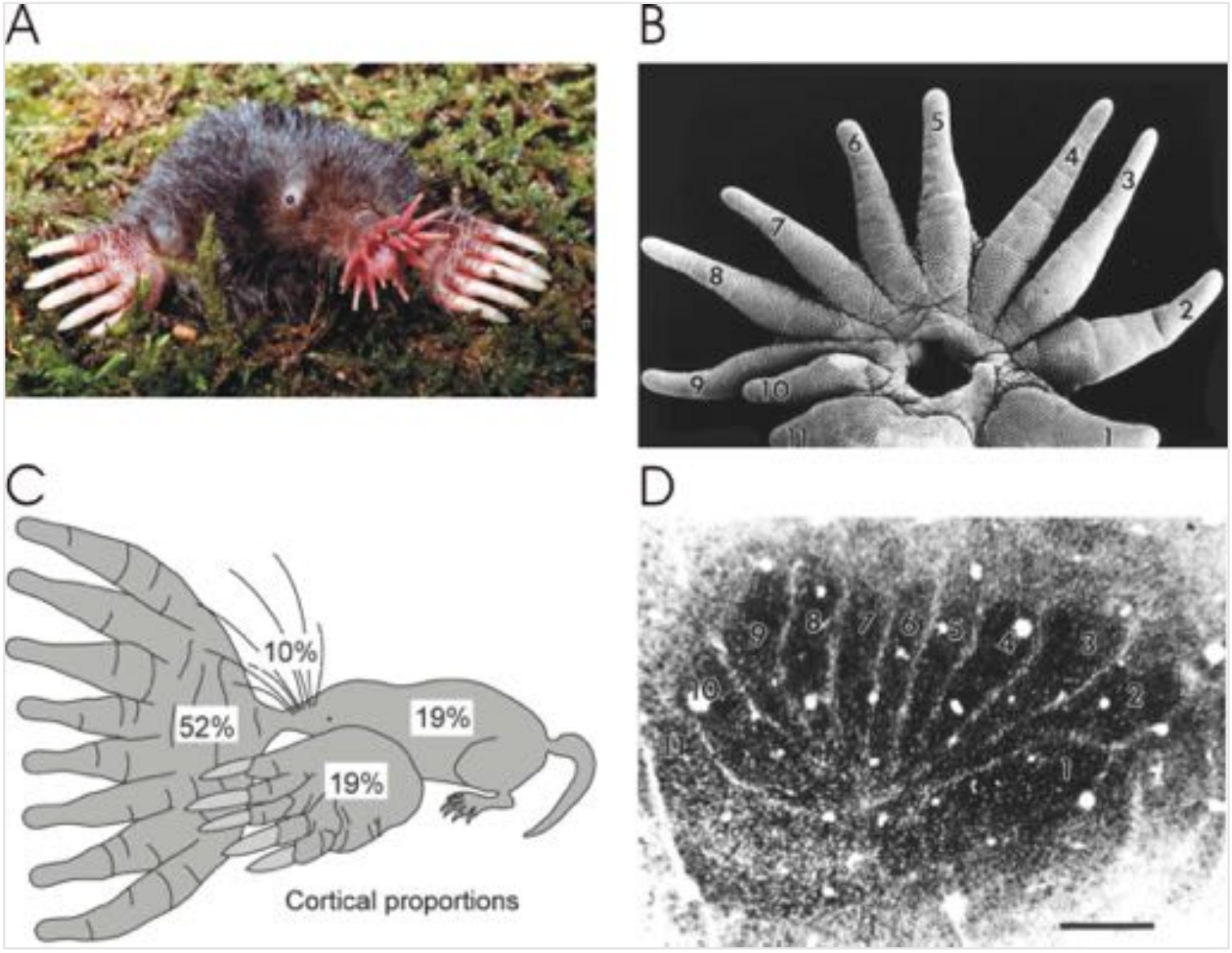
Baltimore (USA), 1955

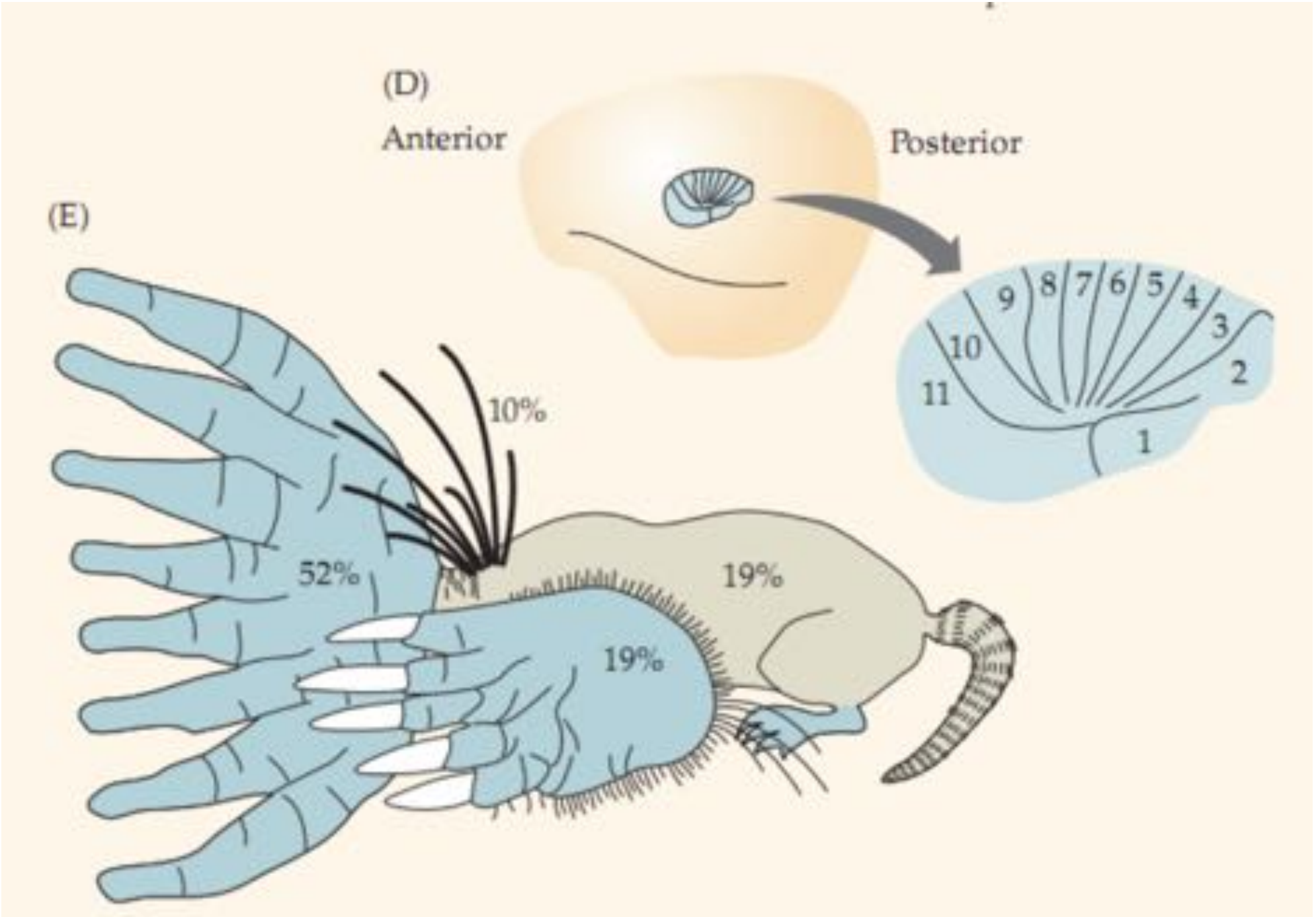
microelectrode conducts signal from individual neurons, or neuron clusters




(A)
3a
3b
1
2
(B)
3b
1
F. Leg
Foot
D5
4
3
2
1
D1
Foot
Foot pads
F. Leg
Foot pads
Foot
A. Leg
d
Trunk
Trunk
d
v
Arm
Arm
Hand
Pads
D5
D4
D3
D2
D1
Tips
Hand
Pads
D5
D4
D3
D2
D1
Tips
Hand
Chin
H
Vib
Vib
Chin
L. Lip
L. Lip
Oral
U. Lip
U. Lip



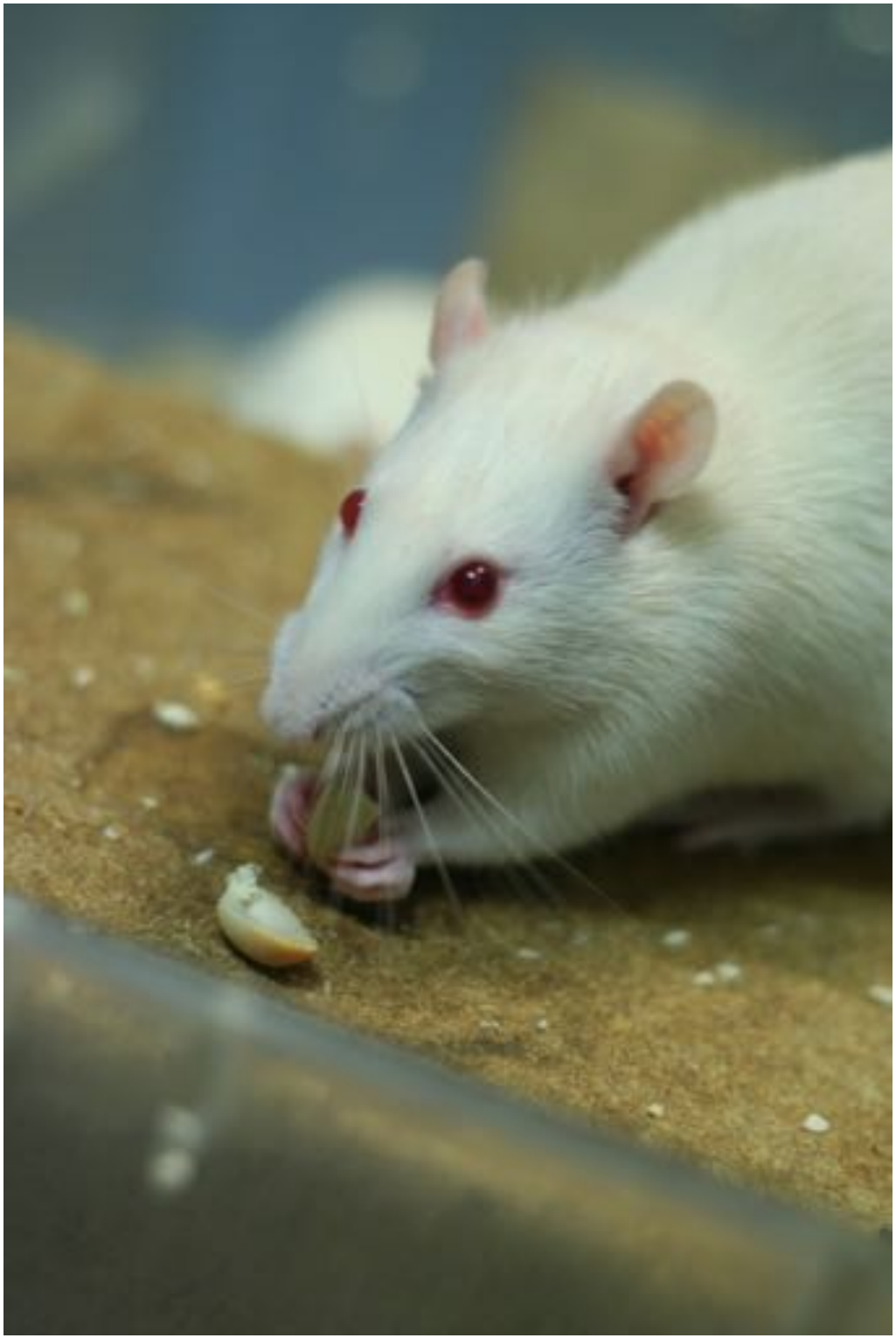

A
B
C
D
10%
52%
19%
19%
Cortical proportions


(D)
Anterior
Posterior
(E)
1
2
3
4
5
6
7
8
9
10
11
10%
52%
19%
19%

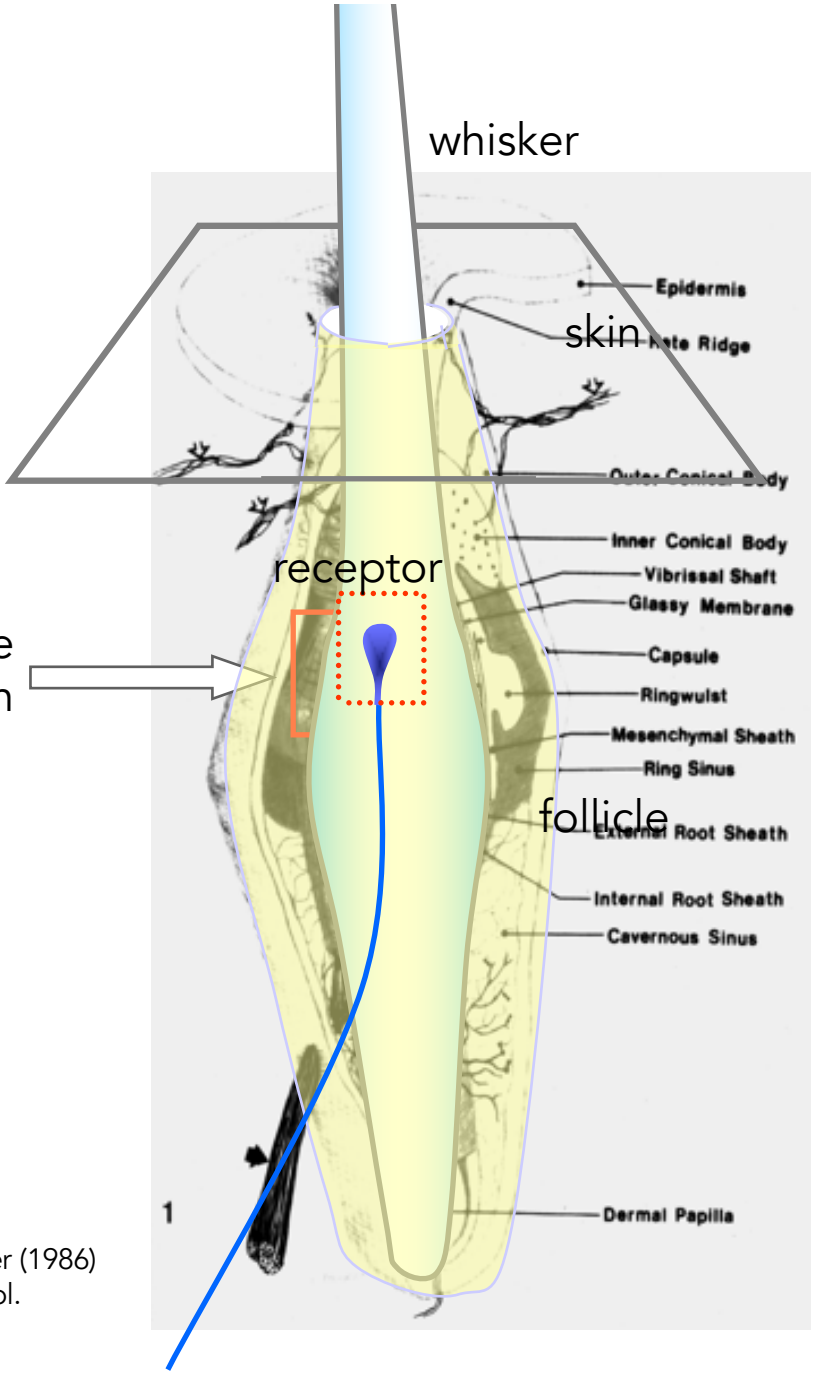
REVIEW

- Neocortex has evolved… largely to accommodate the processing of sensory channels
- Functions are localized - the oldest chapter in Neuroscience
- Within sensory regions, processing is not *disorganized*, but is arrayed in "maps"

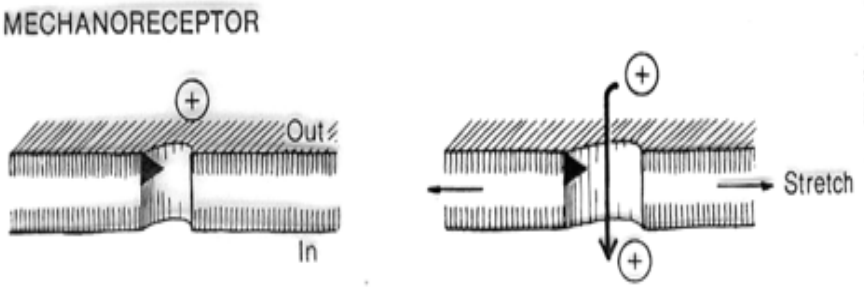
- Maps constrain how we perceive the world
- But maps are the start of the inquiry, not the end

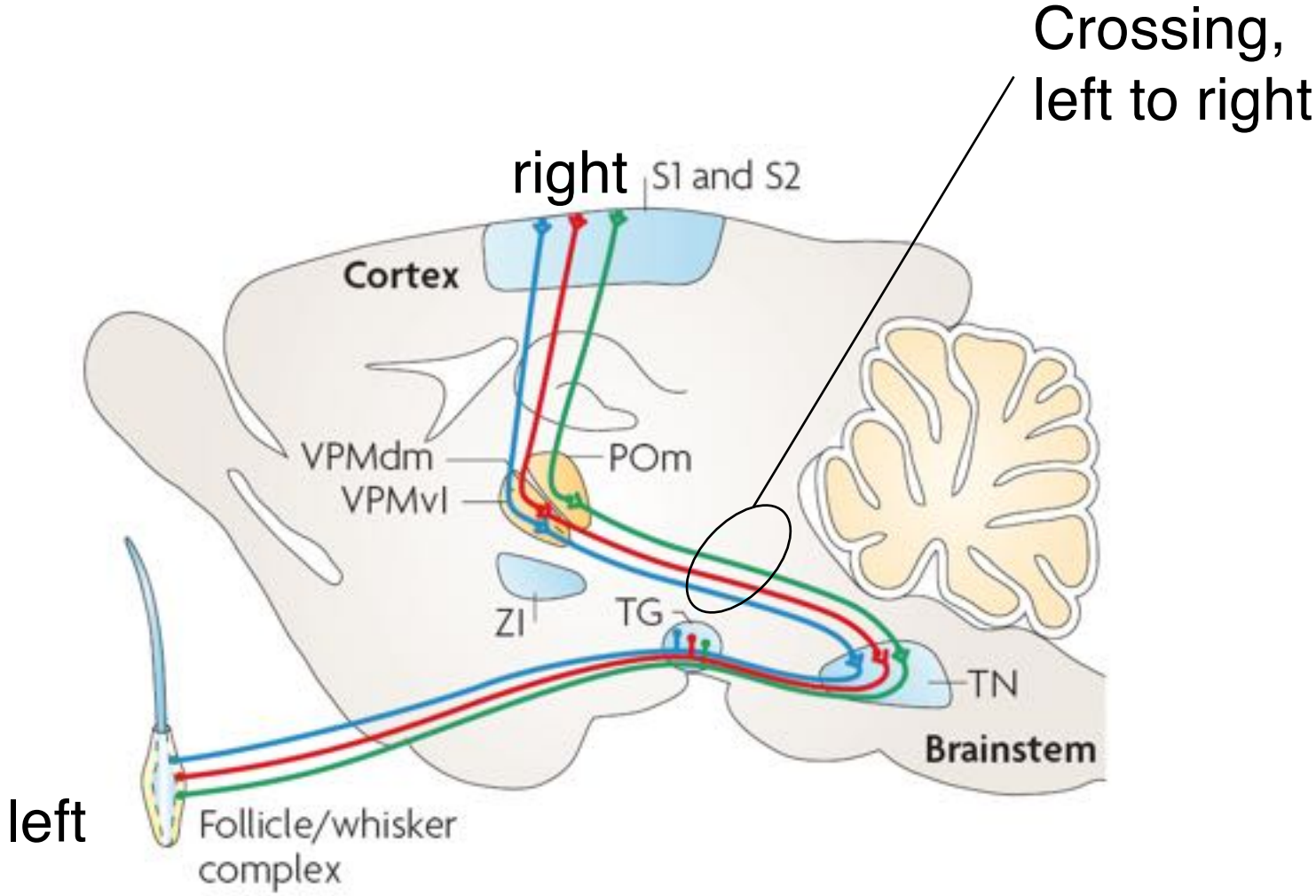


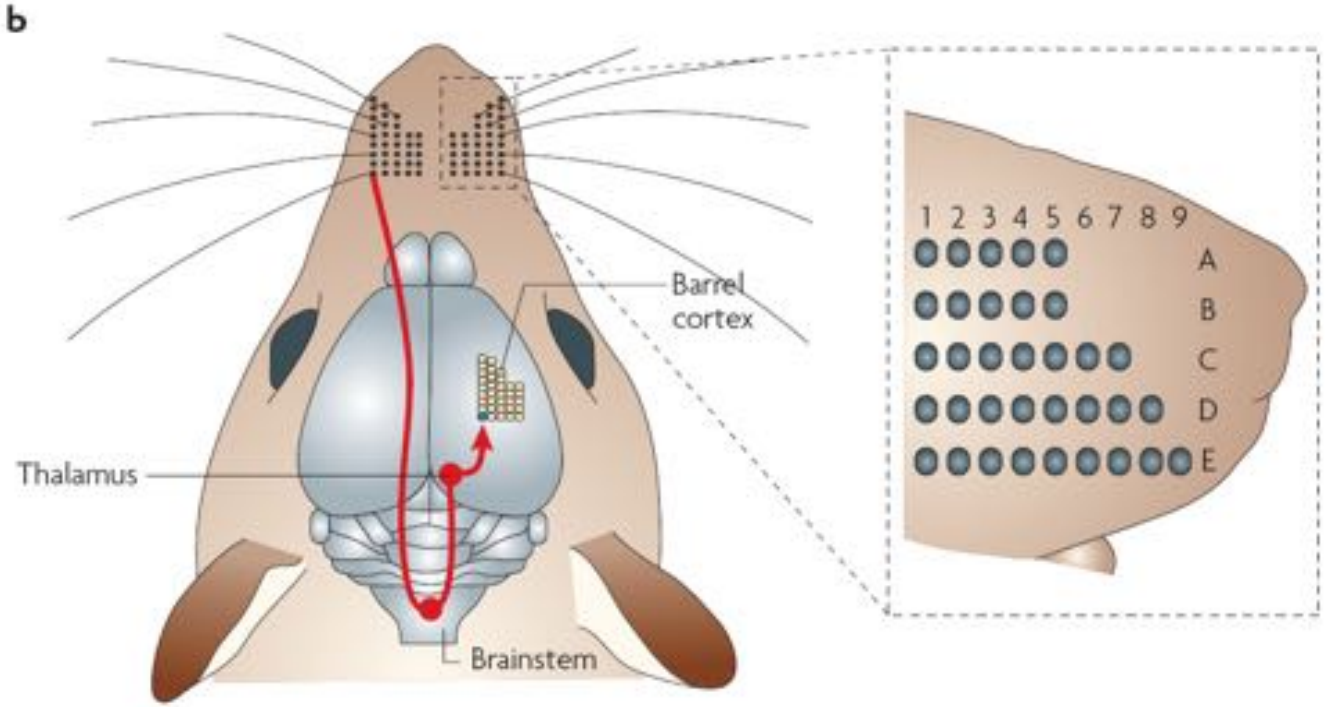
An artistic interpretation of what the newly identified cynodont Bonacynodon schultzi looked like during its lifetime about 235 million years ago during the Triassic. (Jorge Blanco)

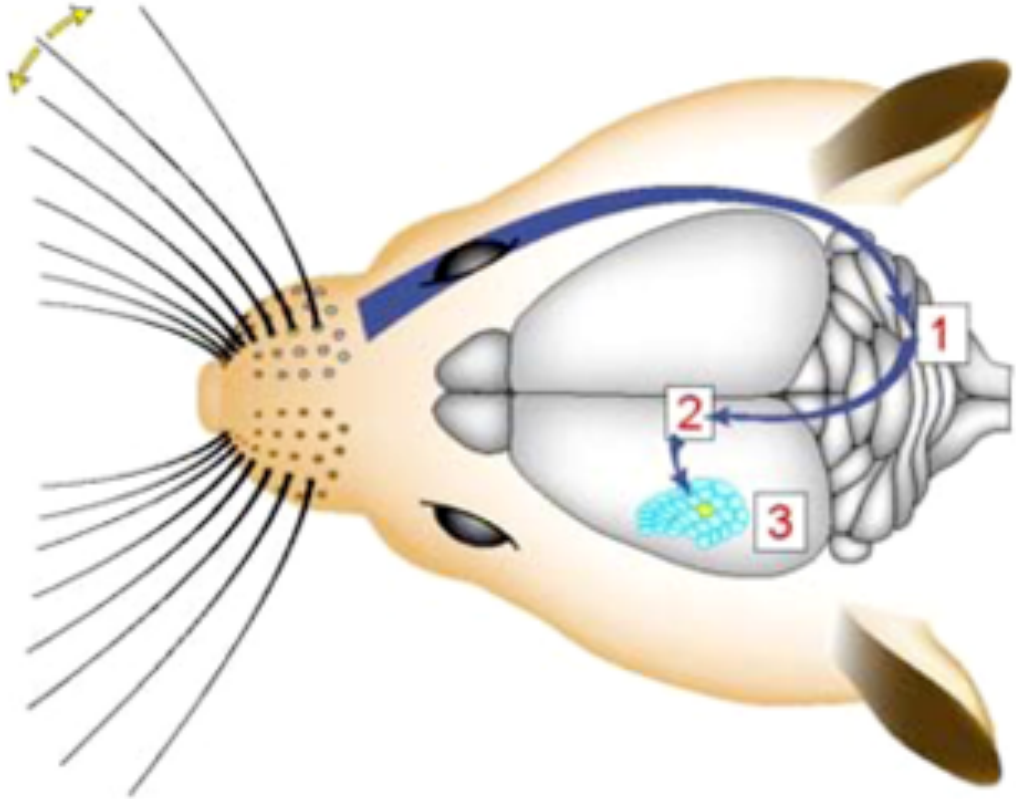


Rice and Munger (1986)
J. Comp. Neurol.

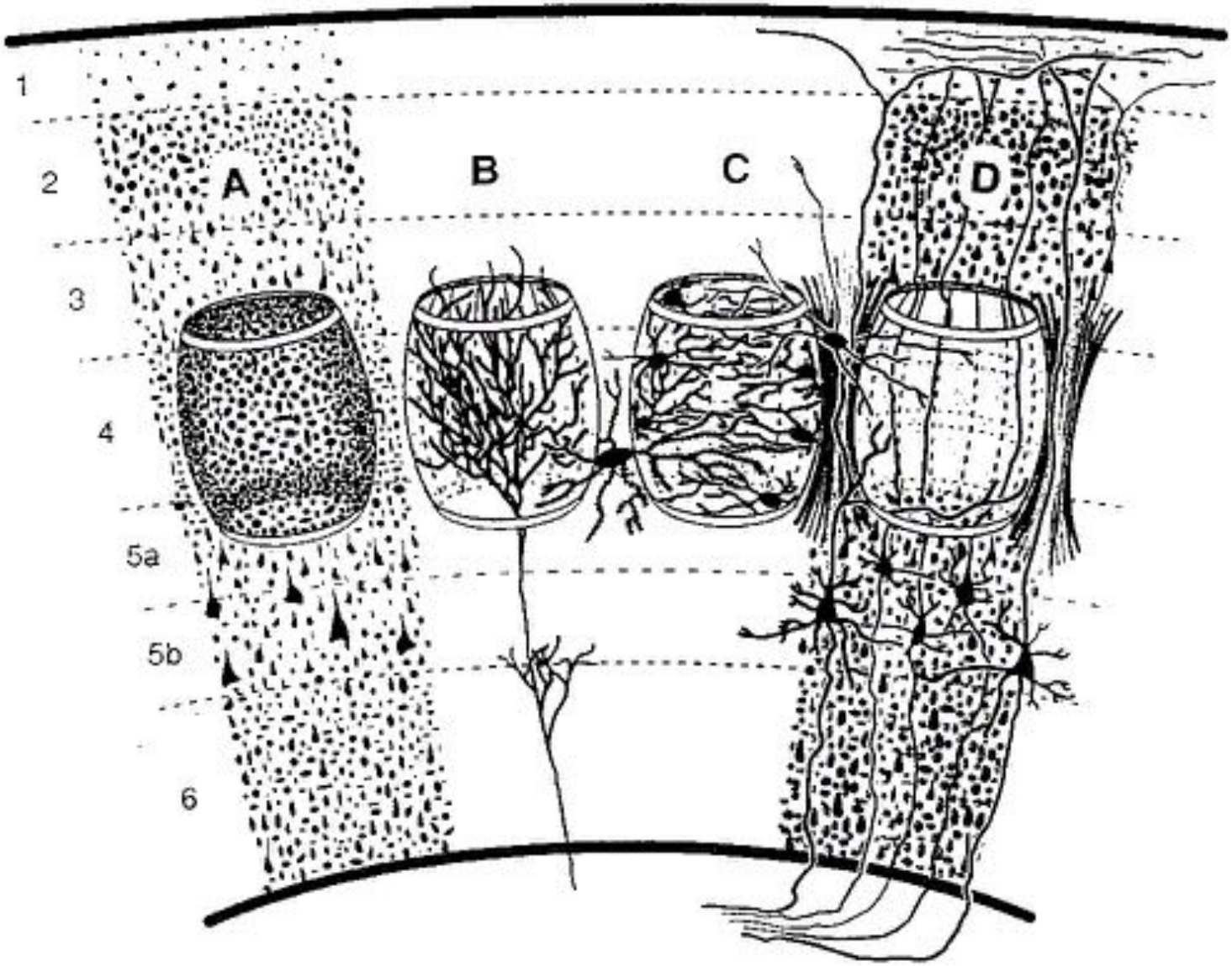



Crossing,
left to right
right
S1 and S2
Cortex
VPMdm
VPMvl
POm
ZI
TG
TN
Brainstem
left
Follicle/whisker
complex
Different kinds of touch receptors
(not relevant for current discussion)


b
Barrel cortex
Thalamus
Brainstem
1 2 3 4 5 6 7 8 9
A
B
C
D
E

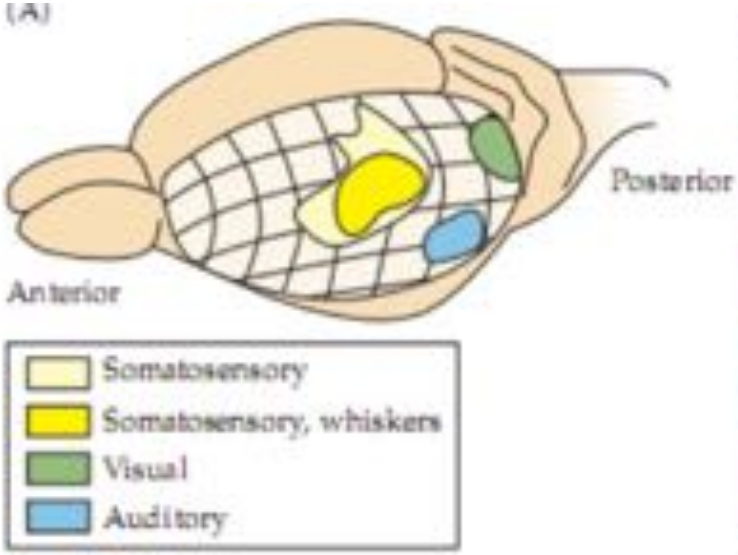

1
2
3

barrel cortex is one of the most robust examples of mammalian columnar organization

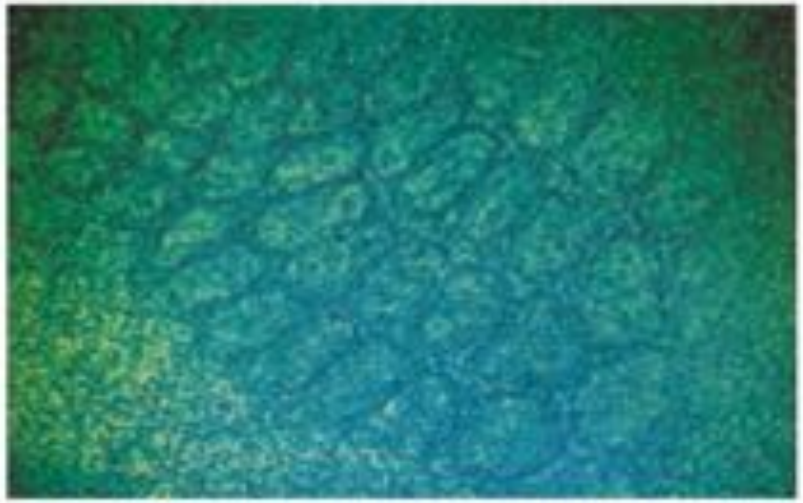


Waite & Tracey (1995)

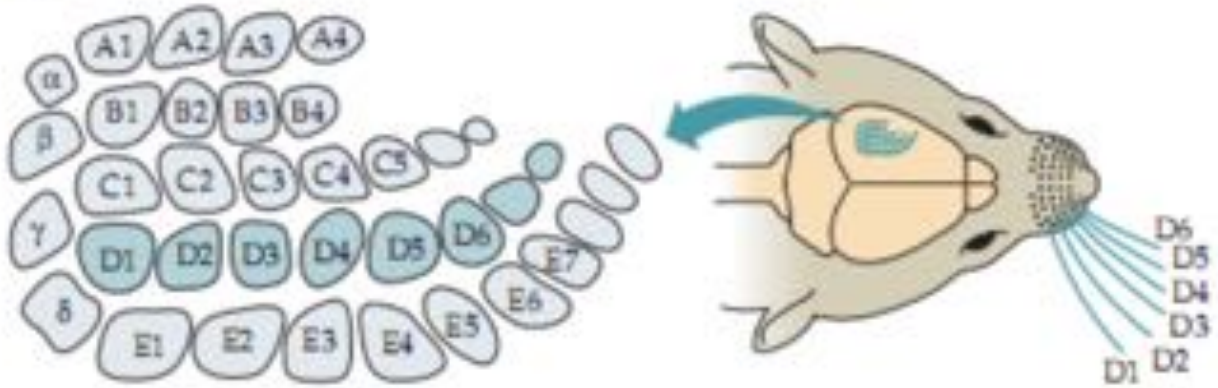
(A)


Posterior
Anterior
Somatosensory
Somatosensory, whiskers
Visual
Auditory

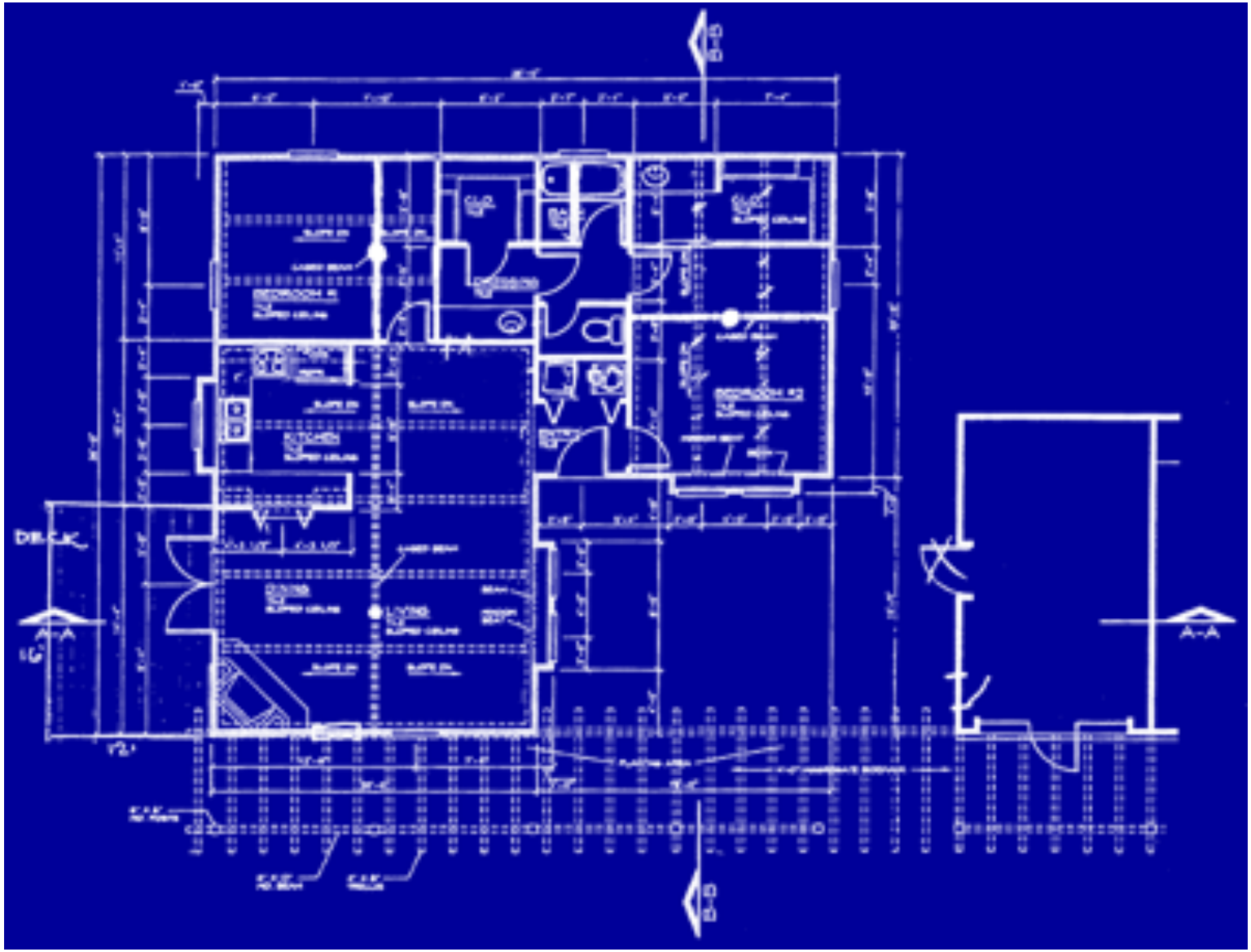
(B)



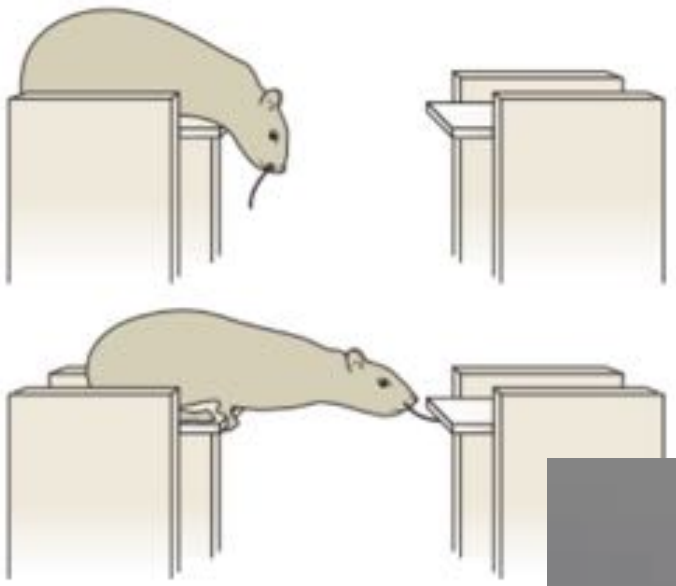
(C)

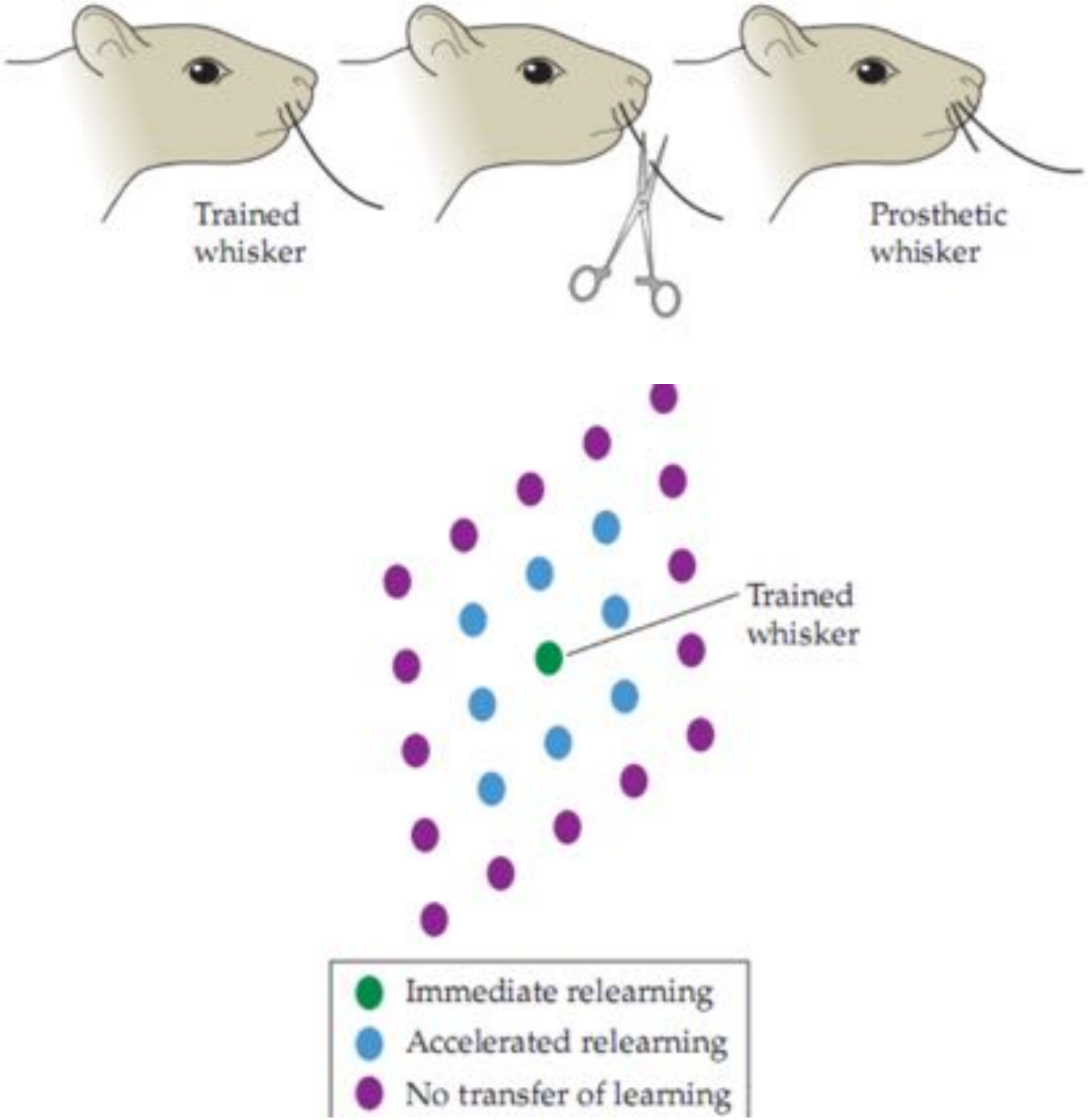

A1
A2
A3
A4
α
B1
B2
B3
B4
β
C1
C2
C3
C4
C5
γ
D1
D2
D3
D4
D5
D6
E7
E6
E5
δ
E1
E2
E3
E4
D6
D5
D4
D3
D2
D1

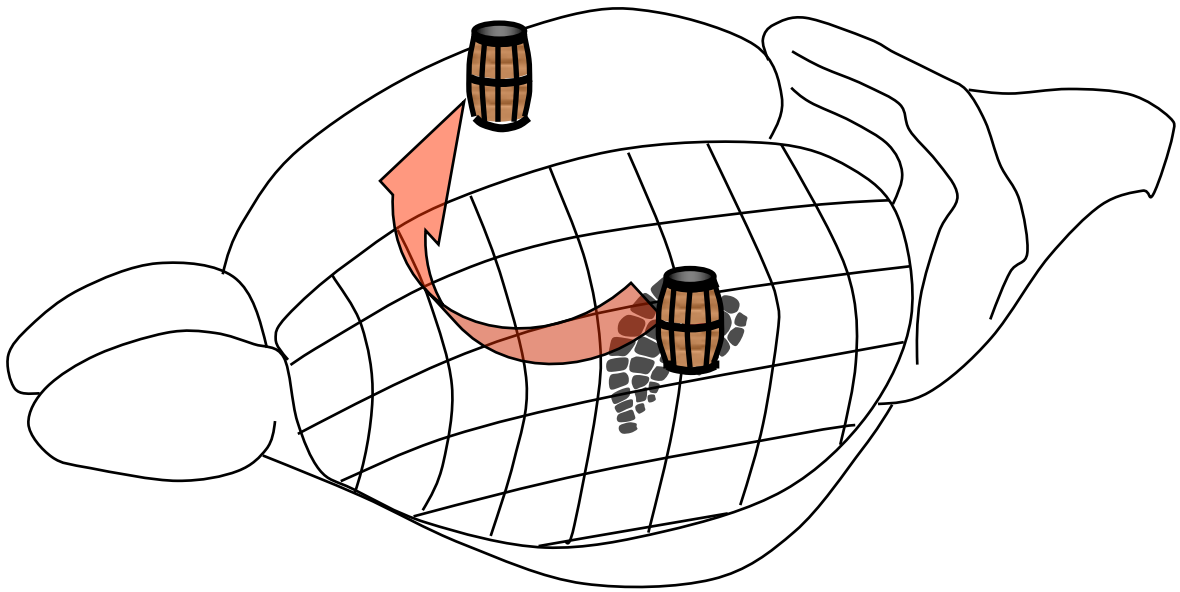
Does the map really
mean anything?



(A)

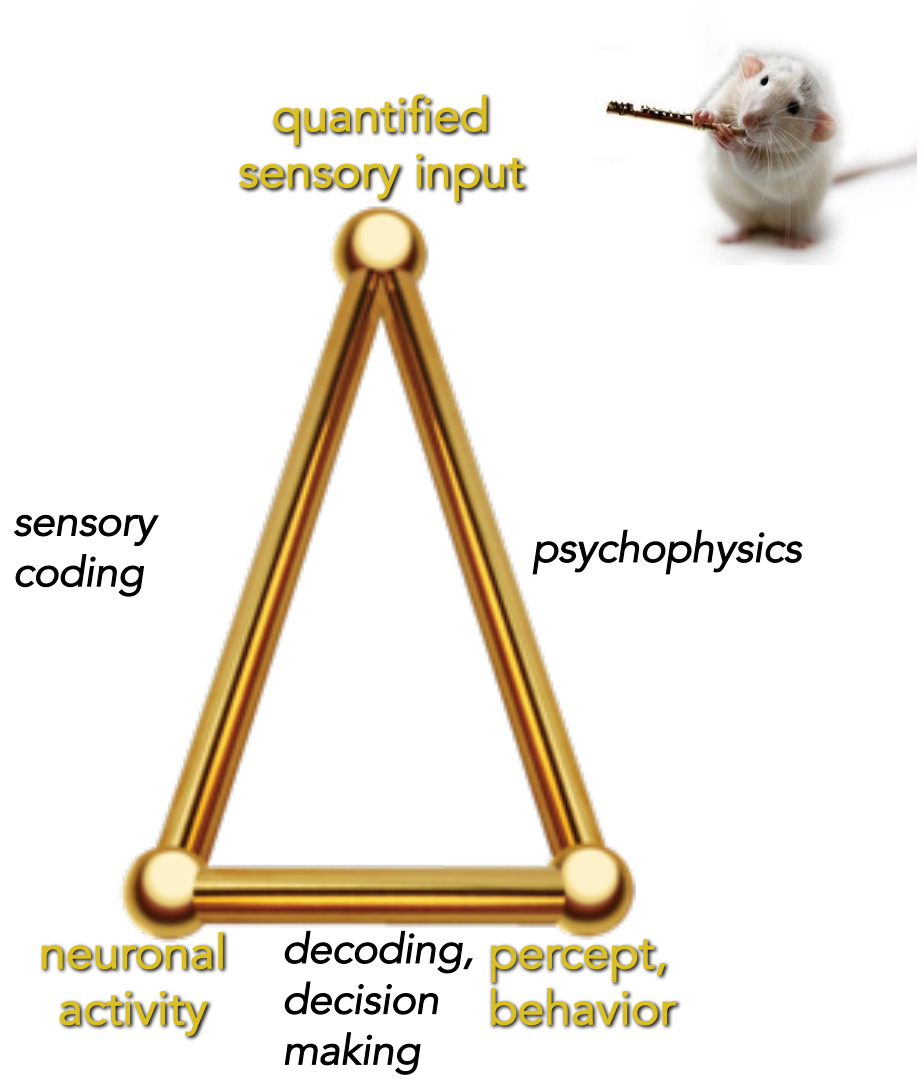



Trained
whisker
Prosthetic
whisker
Trained
whisker
Immediate relearning
Accelerated relearning
No transfer of learning

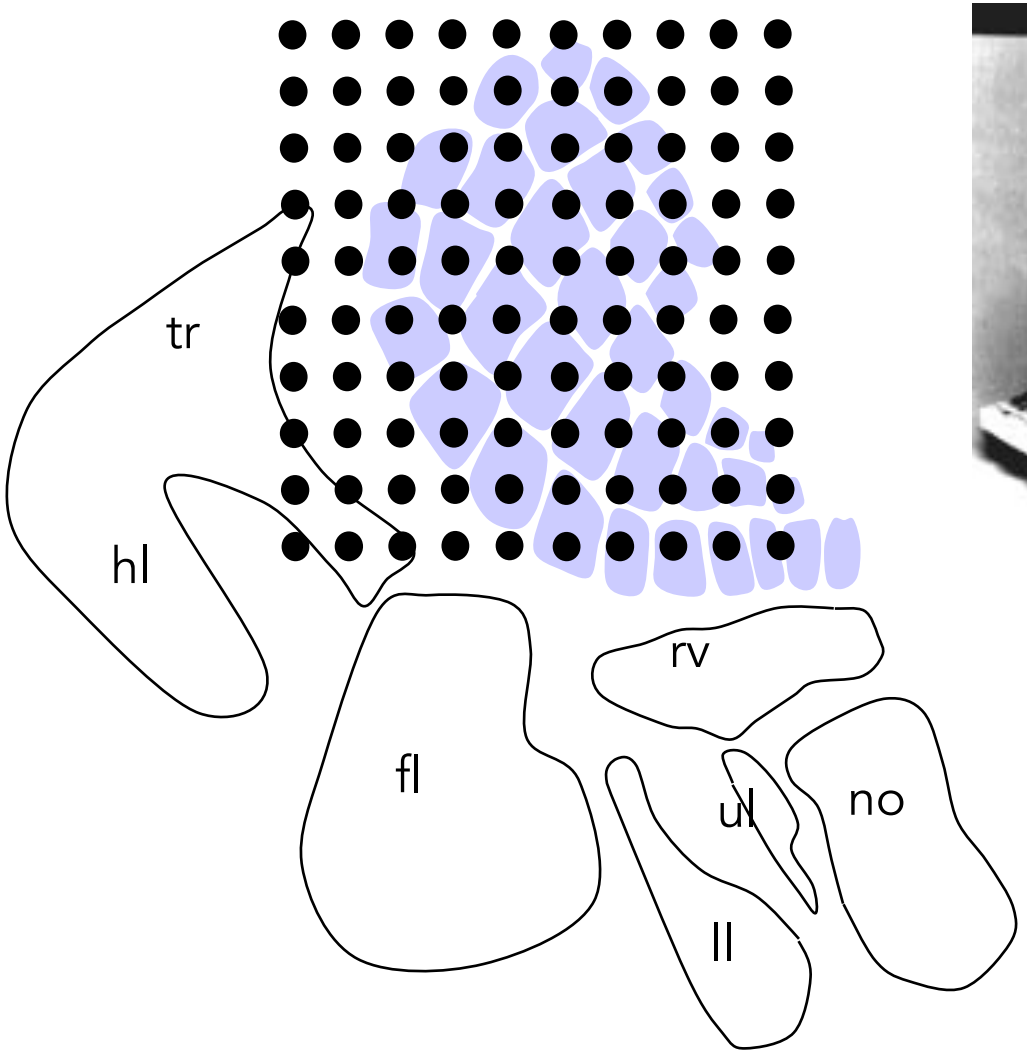


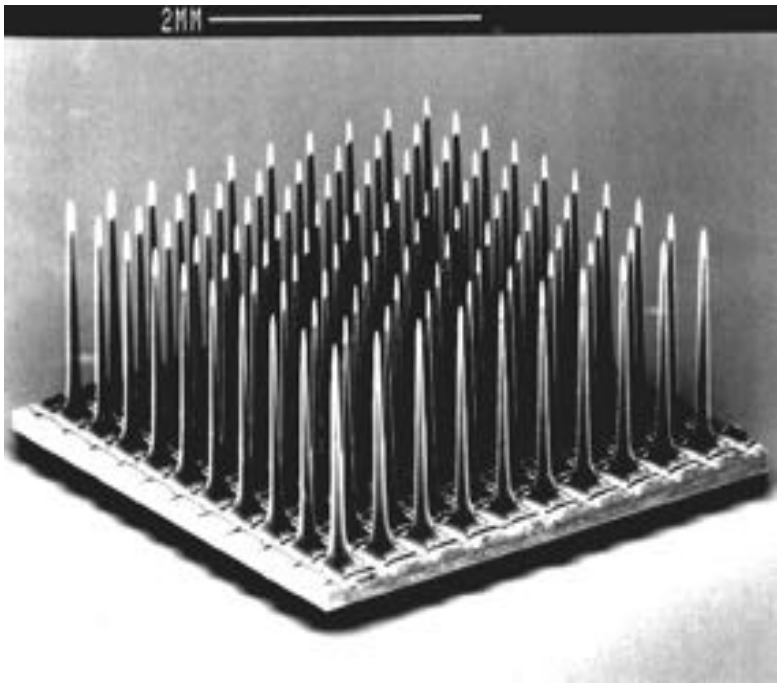
Experimental variables

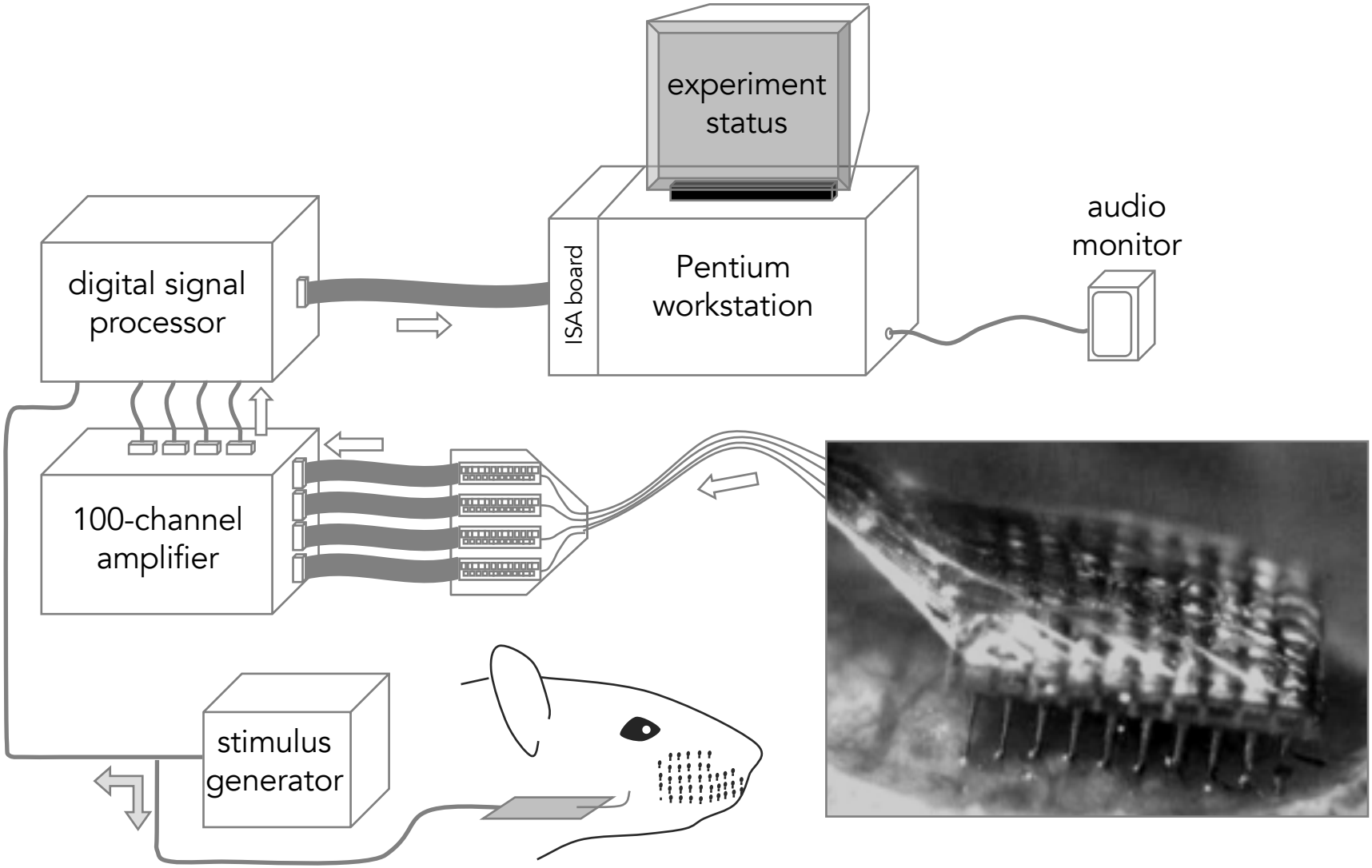
Strategies, approaches



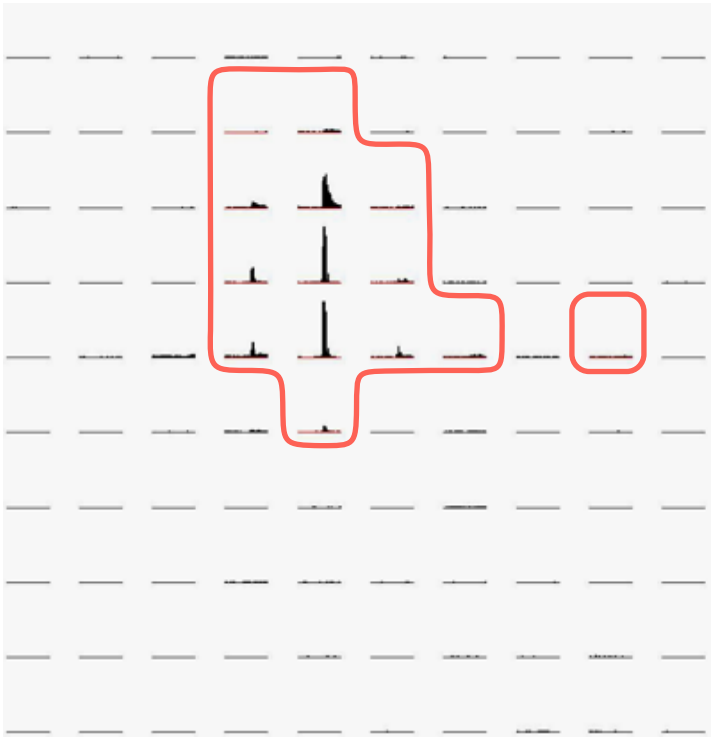
10x10 electrode matrix






experiment
status
audio
monitor
digital signal
processor
ISA board
Pentium
workstation
100-channel
amplifier
stimulus
generator

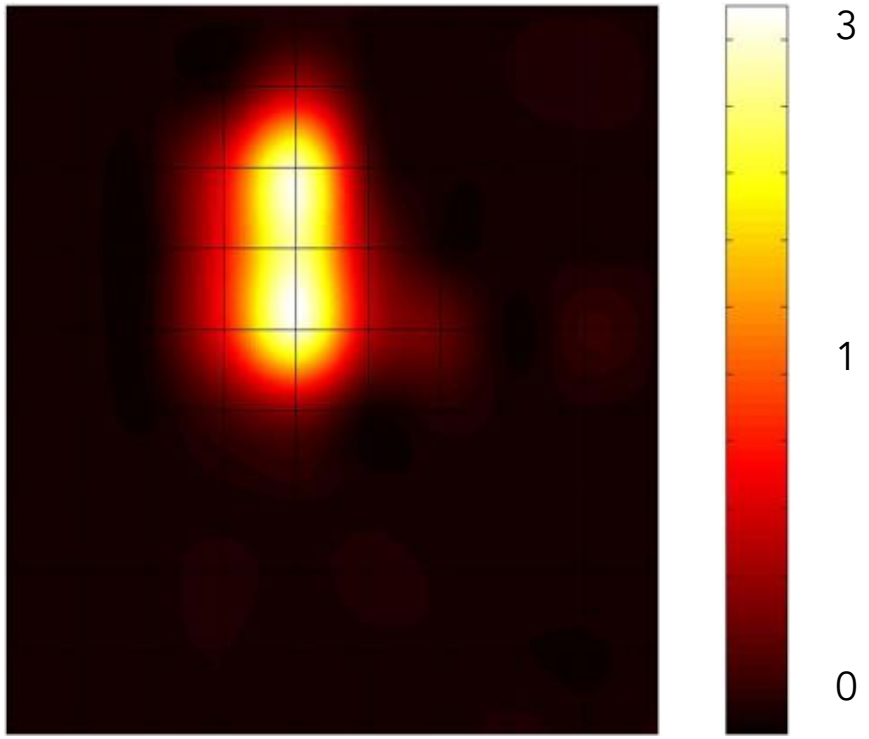
stimulus site C1
multi-unit PSTHs
0-40ms, 5ms bins



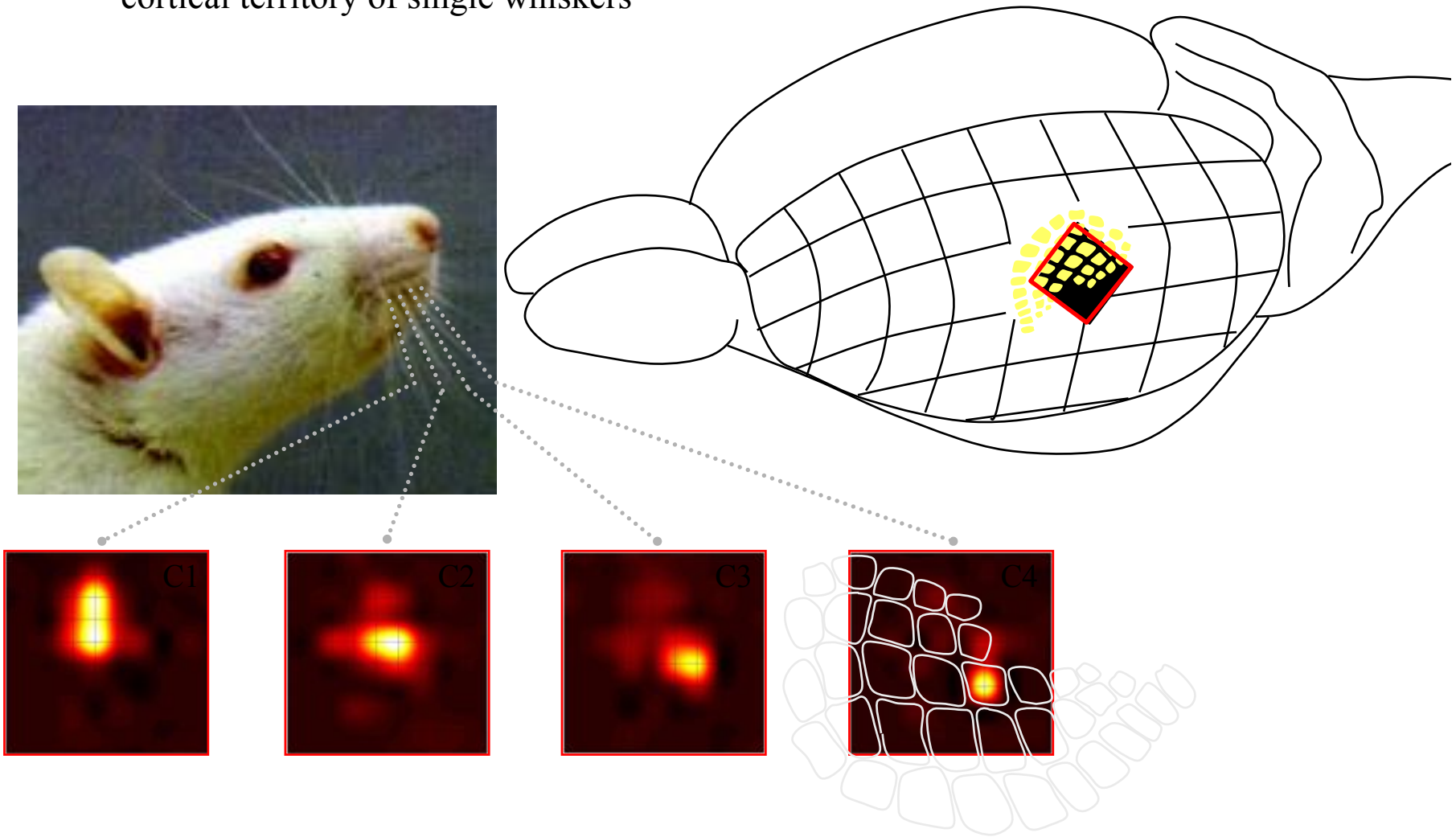
1.0 spikes

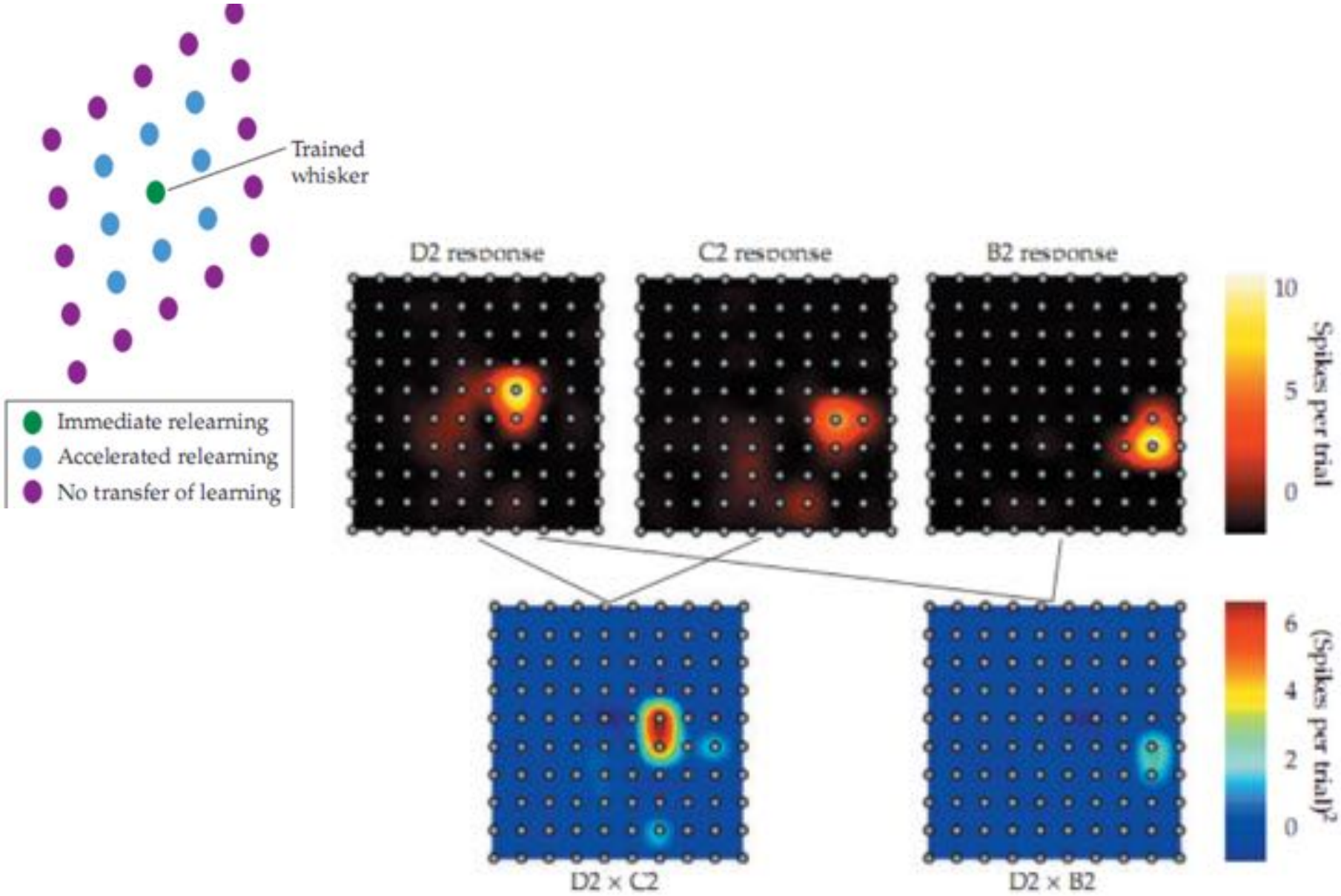
40 ms

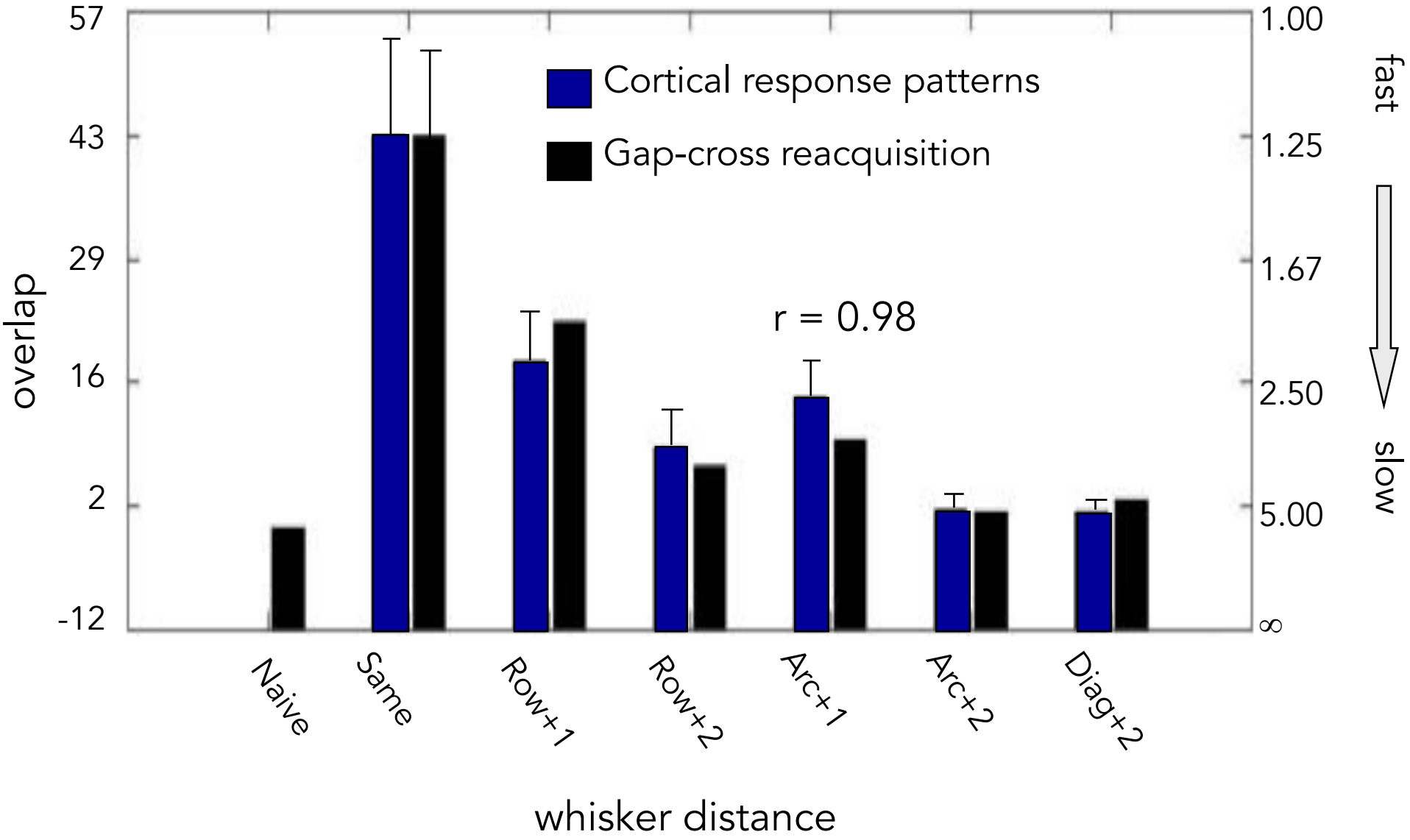
firing rate on each channel
(spikes per trial)
with interpolation



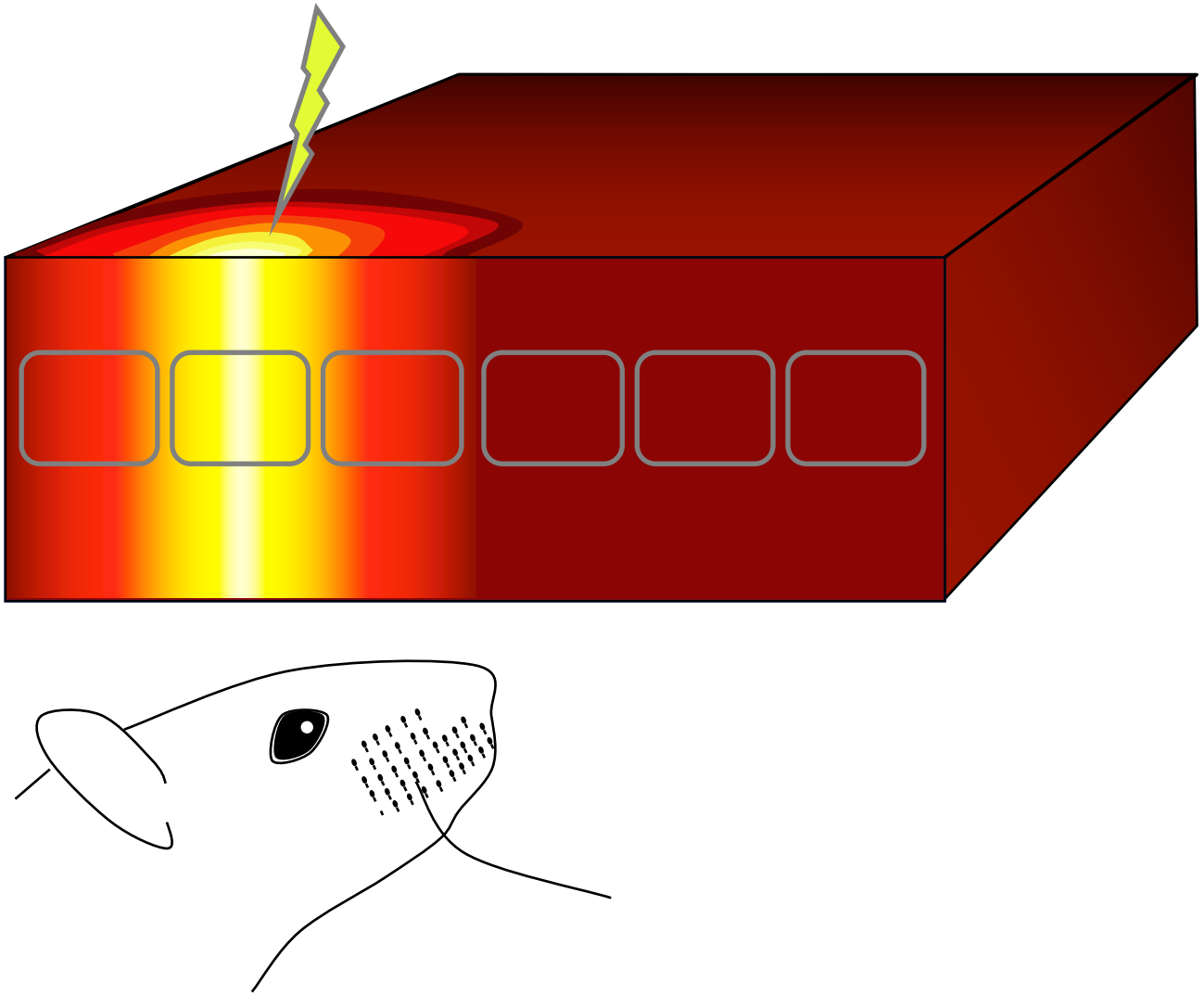
cortical territory of single whiskers



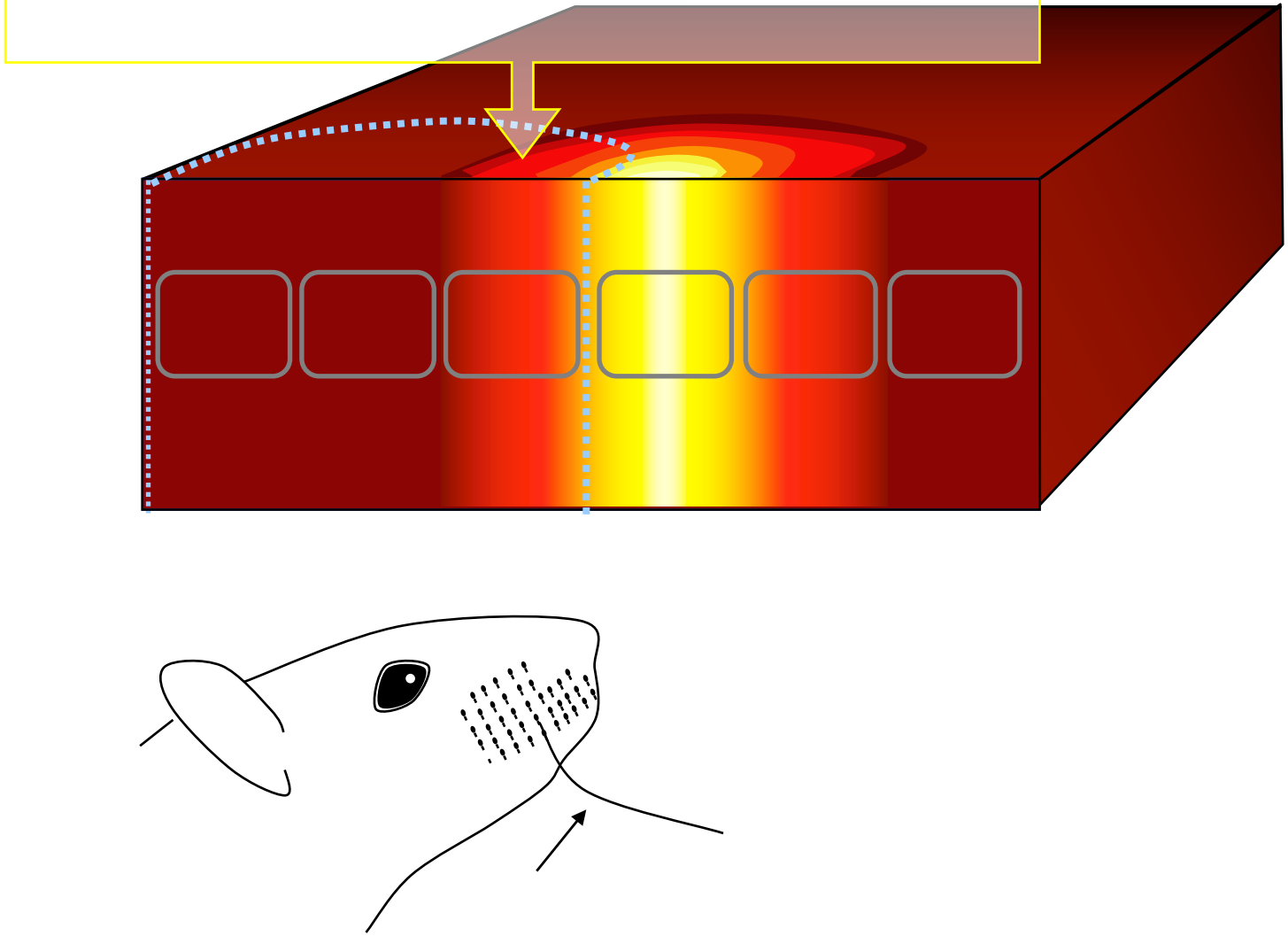

Trained whisker
Immediate relearning
Accelerated relearning
No transfer of learning
D2 response
C2 response
B2 response
10
5
0
Spikes per trial
D2 × C2
D2 × B2
6
4
2
0
(Spikes per trial)²


57
43
29
16
2
-12
overlap
1.00
1.25
1.67
2.50
5.00
∞
fast
slow
Cortical response patterns
Gap-cross reacquisition
r = 0.98
Naive
Same
Row+1
Row+2
Arc+1
Arc+2
Diag+2
whisker distance

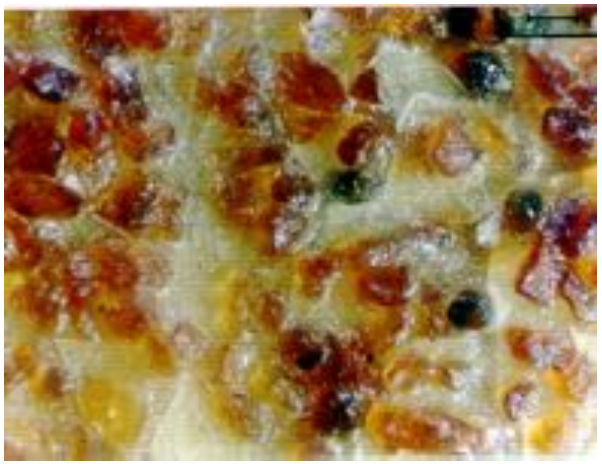
territory in which learned sensory information is stored . . .



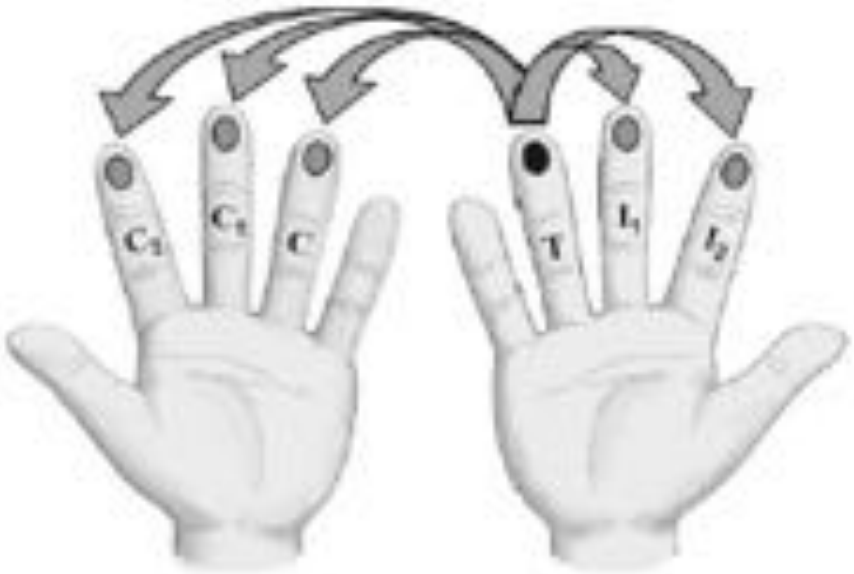
new whisker: common cortical territory

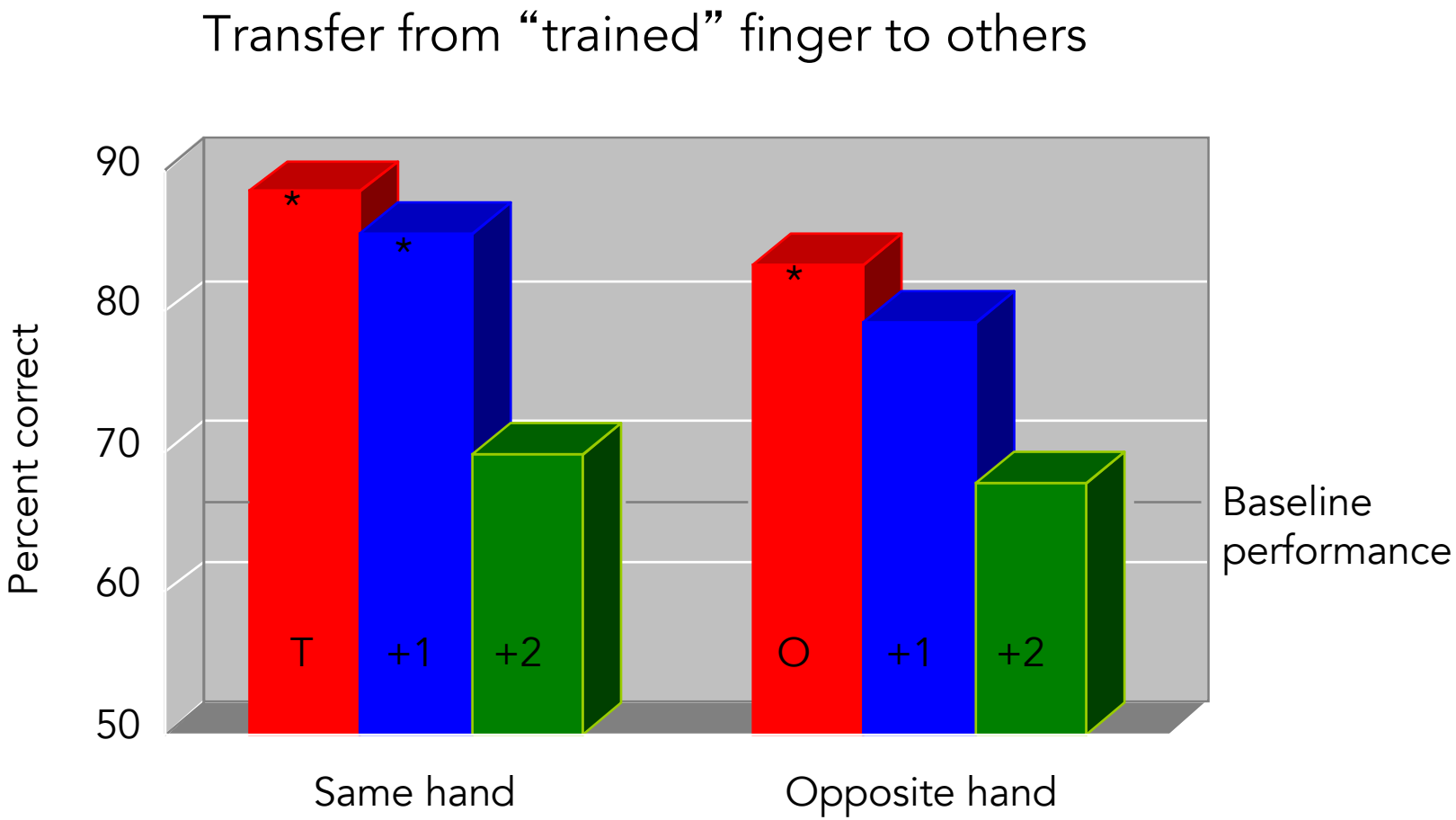


Subjects learned to use one fingertip to discriminate between two grades of sandpaper



400mm




Transfer from “trained” finger to others
Percent correct
90
80
70
60
50
*
*
*
T
+1
+2
O
+1
+2
Baseline performance
Same hand
Opposite hand

So the representation of a signal – either from a whisker or from a fingertip – passes through a bottleneck in the SI map, and some critical form of learning takes place in this restricted territory.

the law of functional localization

cerebral cortex is composed of many anatomically identifiable regions, each of which carries out some special, unique function.

cognitive processes arise from the coordination between functionally specialized processing areas

Geography is the beginning, not the end

Men in Black

Geography is the beginning, not the end

"Area x is involved with task y" does not fully tell us brain function.

What is the message carried by the neurons of area x during task y?

How does that signal, and the transformation carried out by those neurons, contribute to behavior?

Great challenges in Sensory Neuroscience

- *Coding of real, natural stimuli in spike trains*
- *Transformation from coding of physical signals to representation of meaningful objects.*
- *Sensory-motor integration and decision making*
- *Learning, memory, recall*