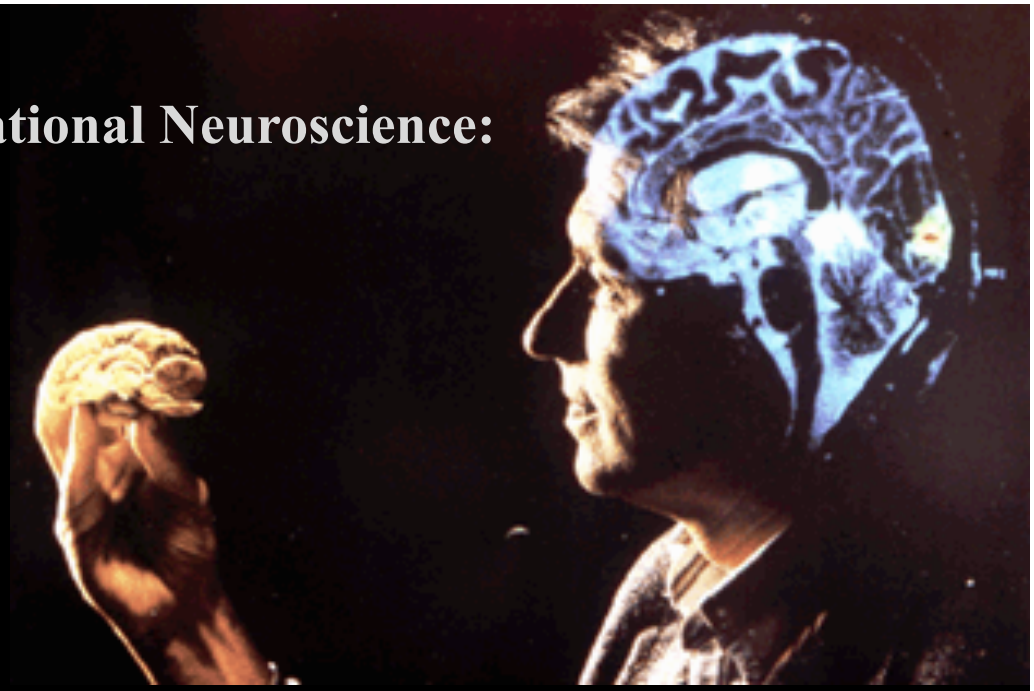
Introduction to Systems and Computational Neuroscience: Tactile Perception



Cognitive Neuroscience is the attempt of our nervous system to understand itself.
(think about that for a second!!)

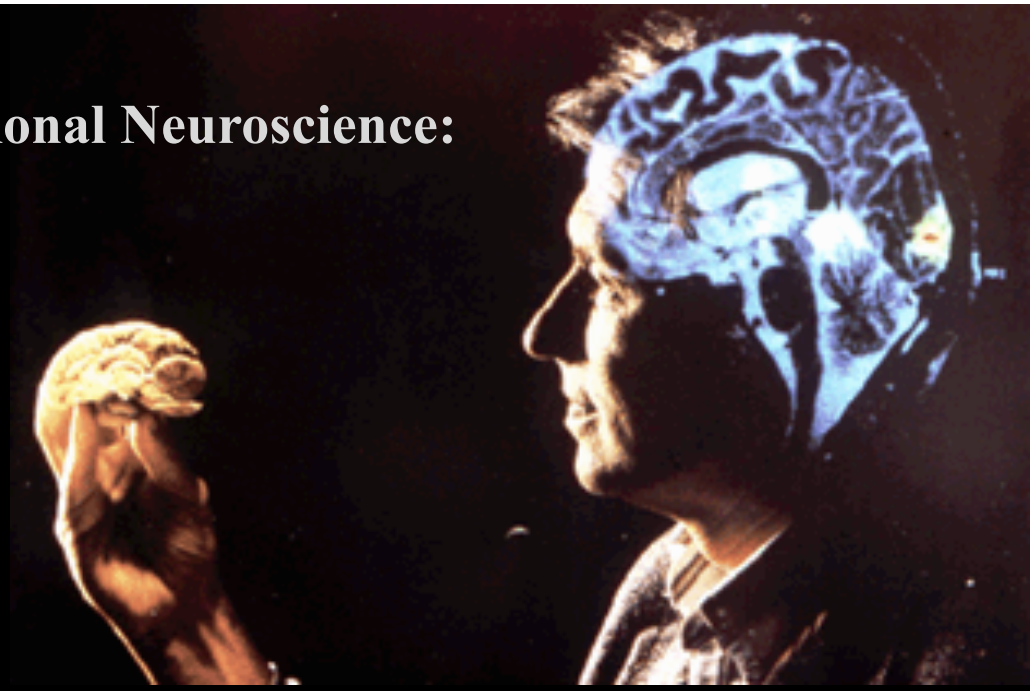
intelligence

We are intelligent enough to understand our own intelligence

curiousity

We just don't care

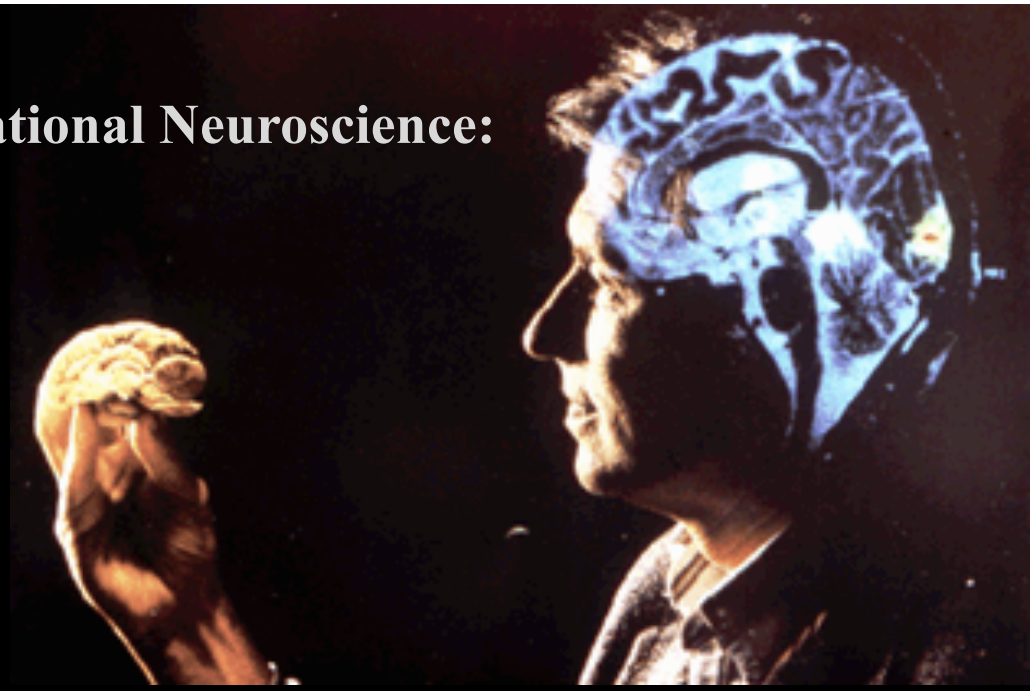
Introduction to Systems and Computational Neuroscience: Tactile Perception



Cognitive Neuroscience is the attempt of our nervous system to understand itself. (think about that for a second!!)

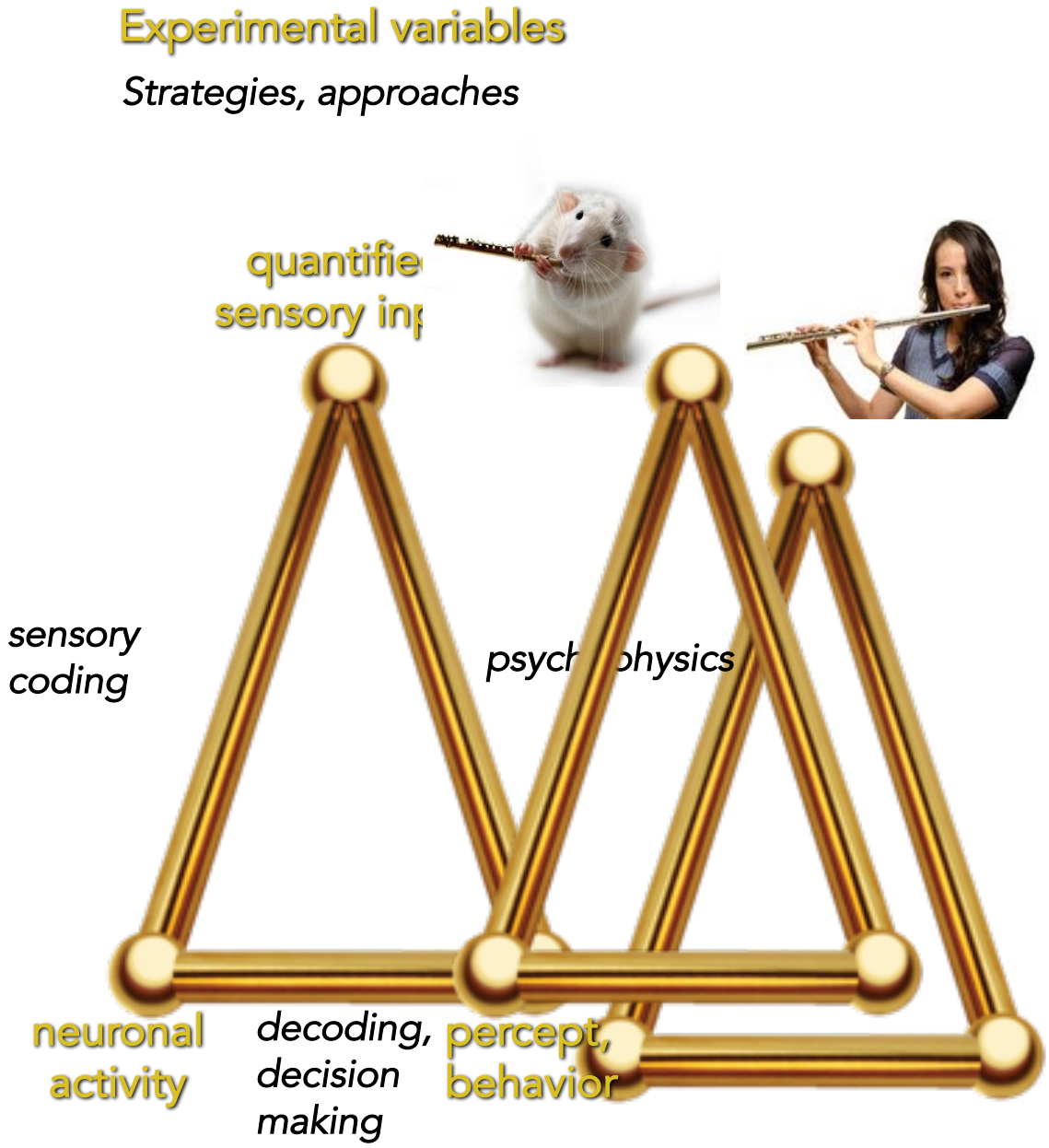
This section of the course will provide an introduction to current knowledge about the neuronal processes involved in sensation and perception.

Introduction to Systems and Computational Neuroscience: Tactile Perception



LESSON 1.
INTRODUCTION TO THE STUDY OF CORTEX

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



… but the golden triangle will come later.

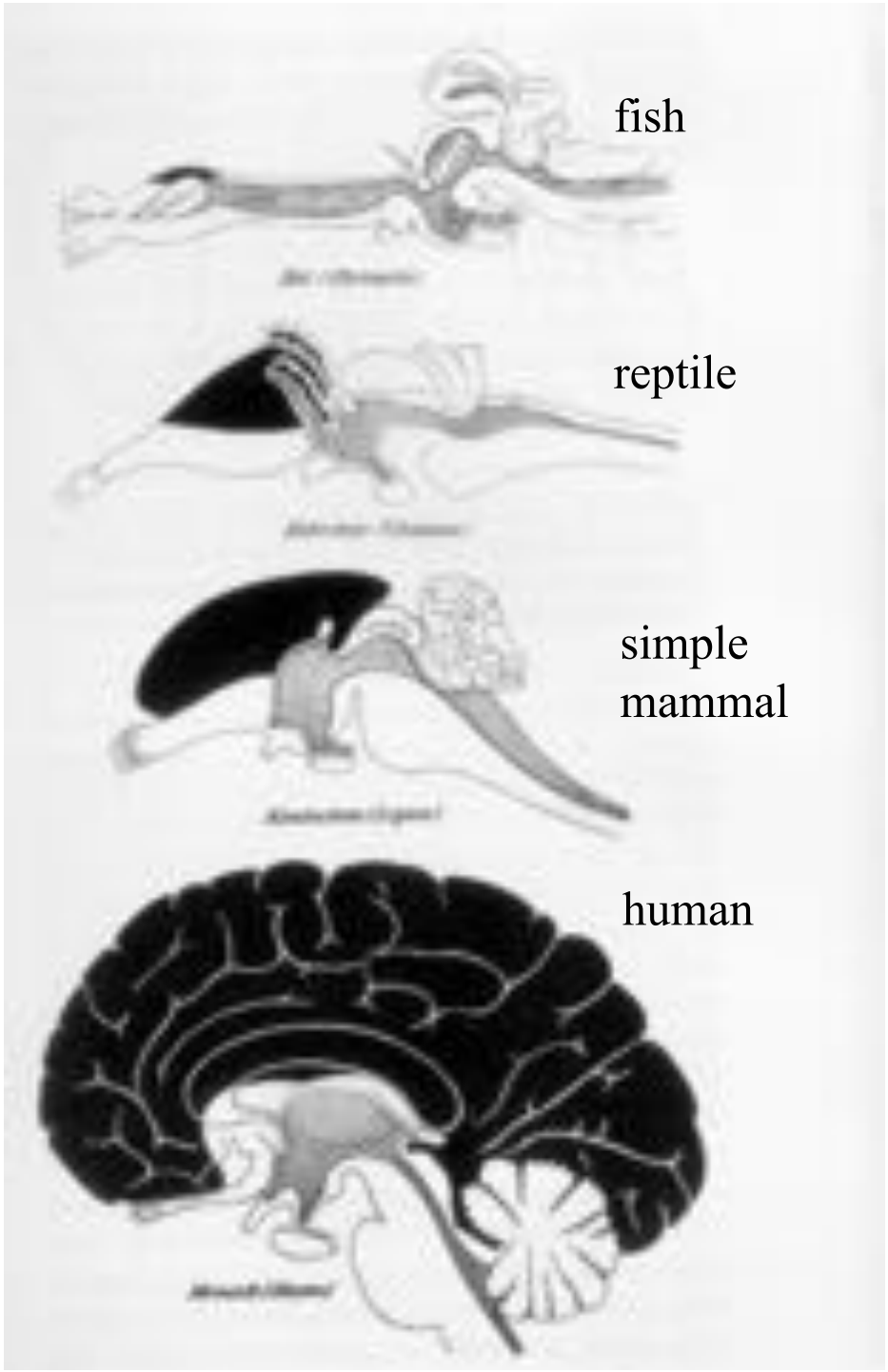
Today the minimum knowledge of cortical organization to begin to approach sensory systems.

- 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

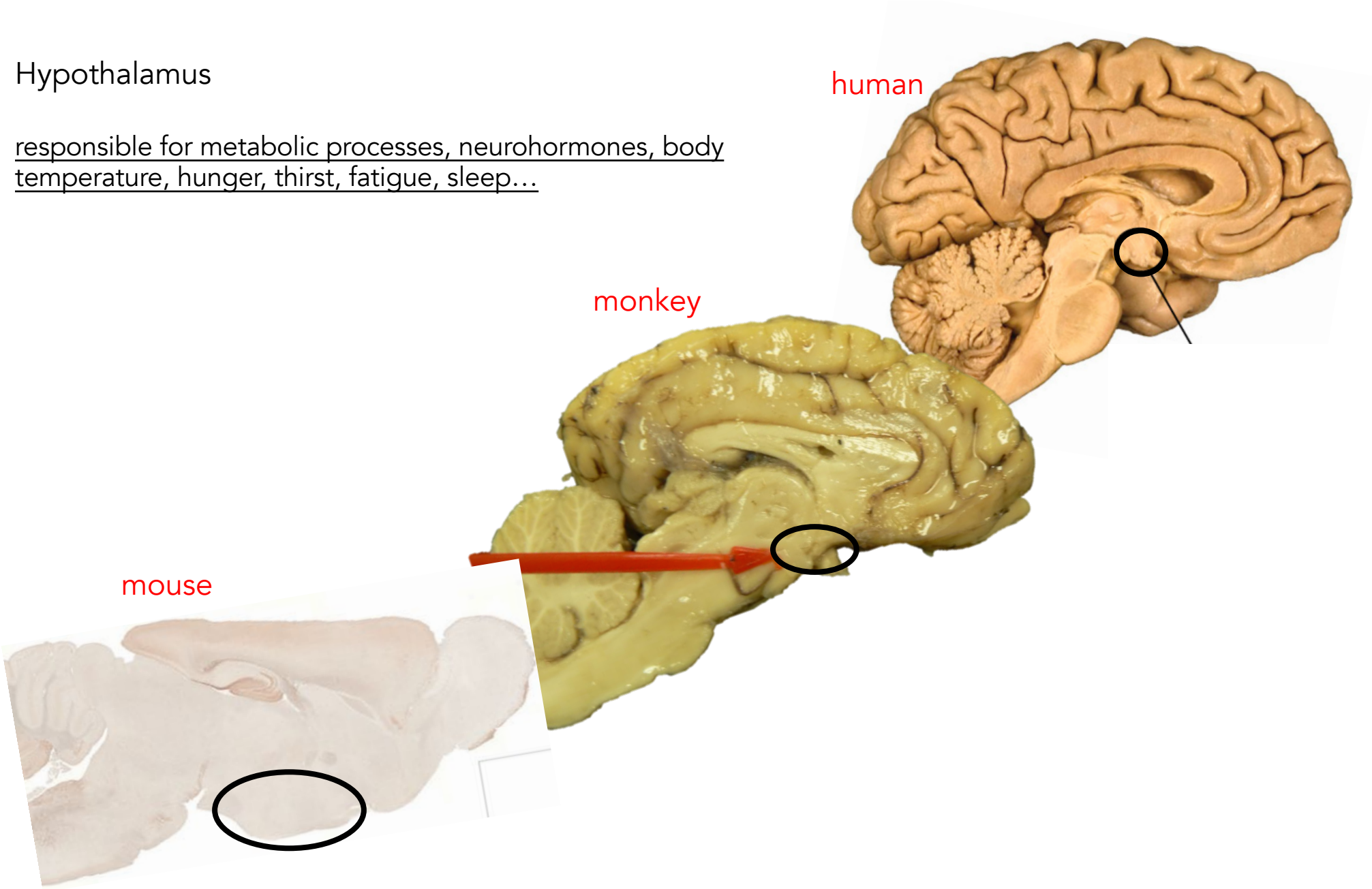
Cerebral cortical evolution:
cerebral cortex / whole brain increases

See Treves lectures

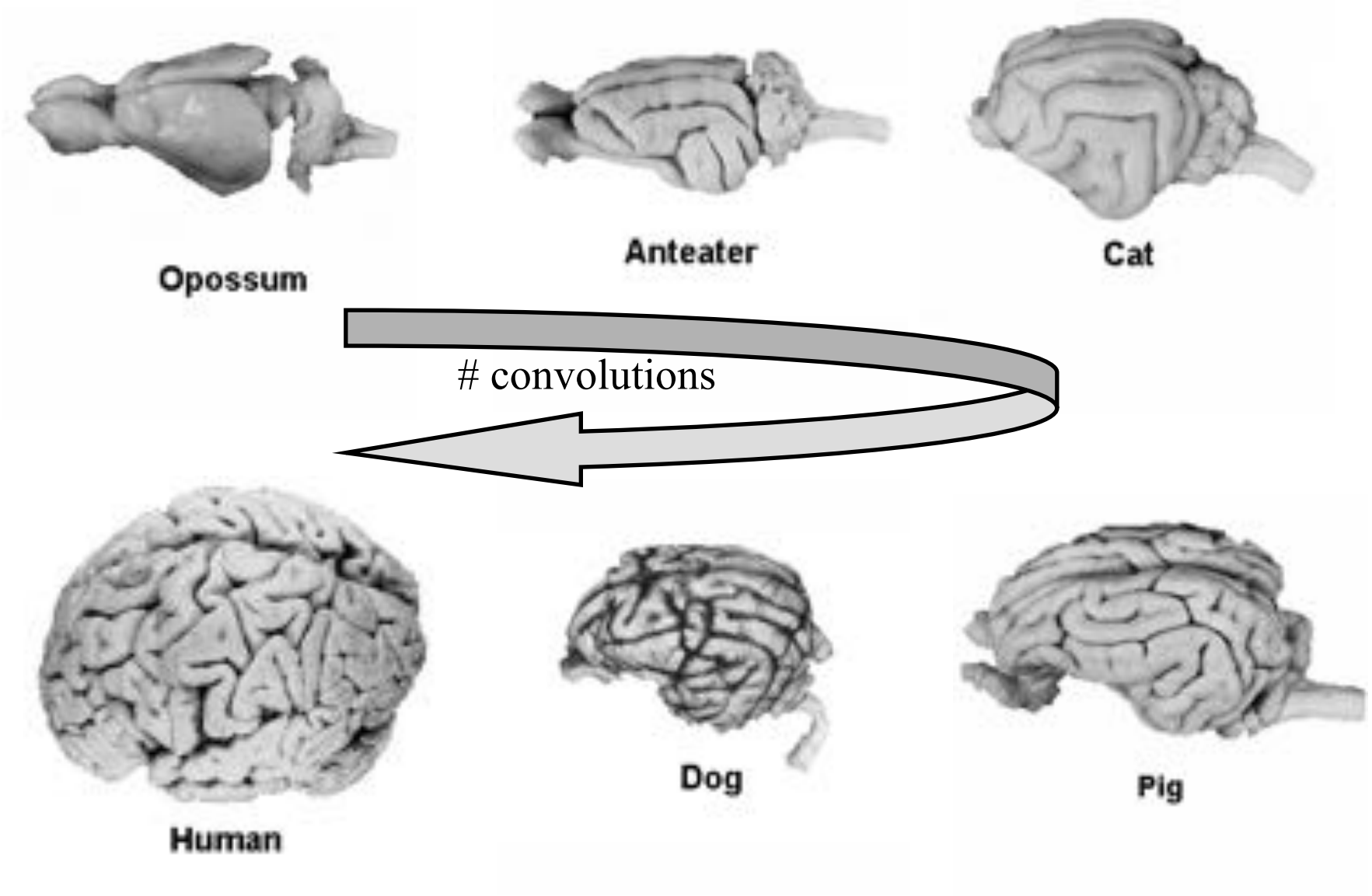


Hypothalamus

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



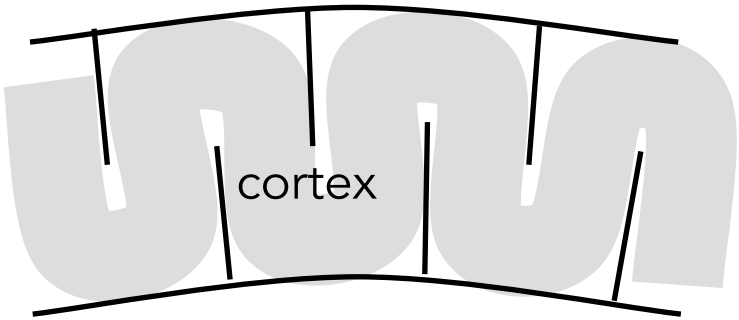
(brain images rescaled to similar size for illustration)


Opossum
Anteater
Cat
convolutions
Human
Dog
Pig

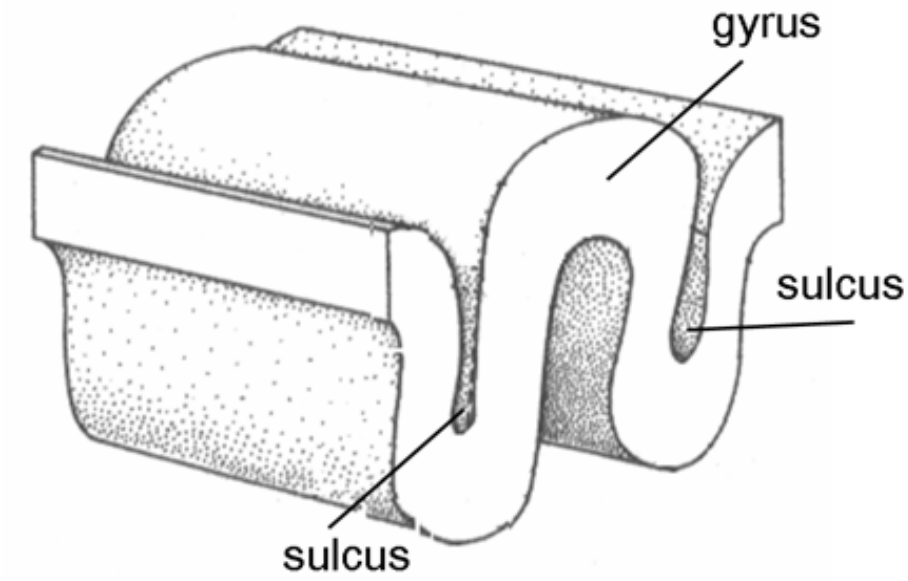
unconvoluted
"lissencephalic"

subcortical tissue

convoluted
"gyrencephalic"



subcortical tissue



To expand volume, why not just increase thickness?

Science 3 July 2015:
Vol. 349 no. 6243 pp. 74-77
DOI: 10.1126/science.aaa9101

REPORT

Cortical folding scales universally with surface area and thickness, not number of neurons

Bruno Mota[1], Suzana Herculano-Houzel[2,3,*]

+ Author Affiliations

*Corresponding author. E-mail: suzanahh@gmail.com

ABSTRACT EDITOR'S SUMMARY

Larger brains tend to have more folded cortices, but what makes the cortex fold has remained unknown. We show that the degree of cortical folding scales uniformly across lissencephalic and gyrencephalic species, across individuals, and within individual cortices as a function of the product of cortical surface area and the square root of cortical thickness. This relation is derived from the minimization of the effective free energy associated with cortical shape according to a simple physical model, based on known mechanisms of axonal elongation. This model also explains the scaling of the folding index of crumpled paper balls. We discuss the implications of this finding for the evolutionary and developmental origin of folding, including the newfound continuum between lissencephaly and gyrencephaly, and for pathologies such as human lissencephaly.

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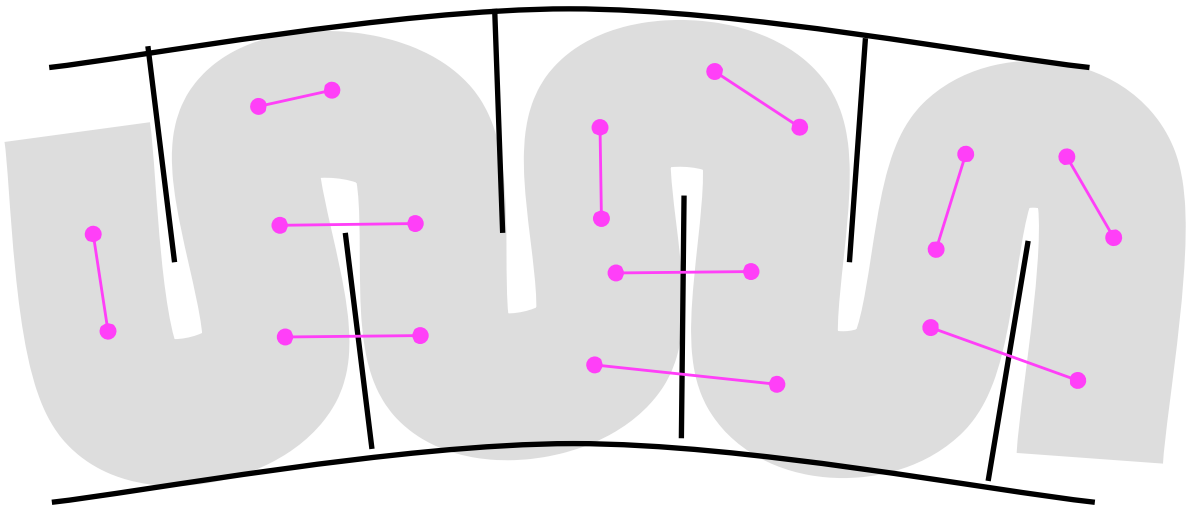
What does this mean??

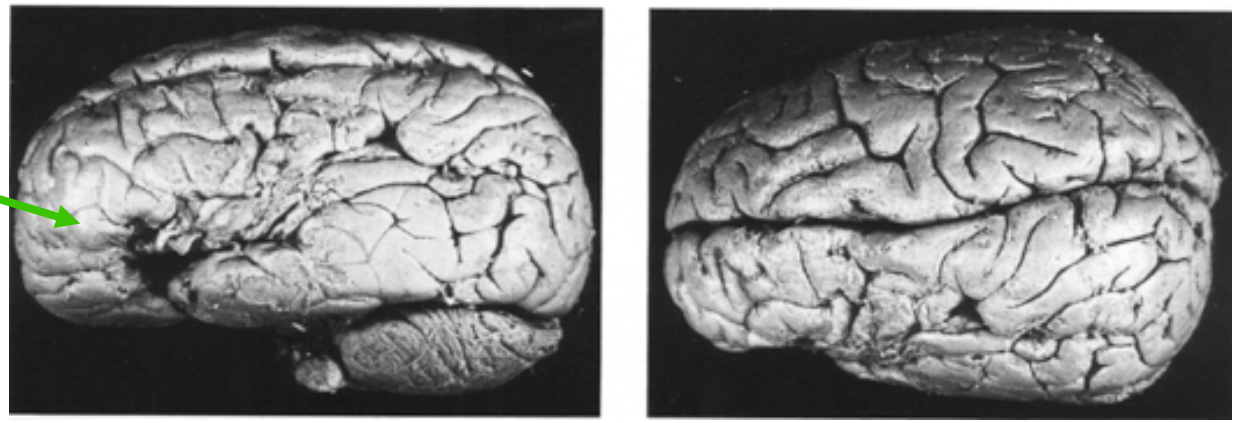


Localization of function

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

David Ferrier

In humans, luck (usually bad luck) determines lesion site

Controlled, limited lesions in animals

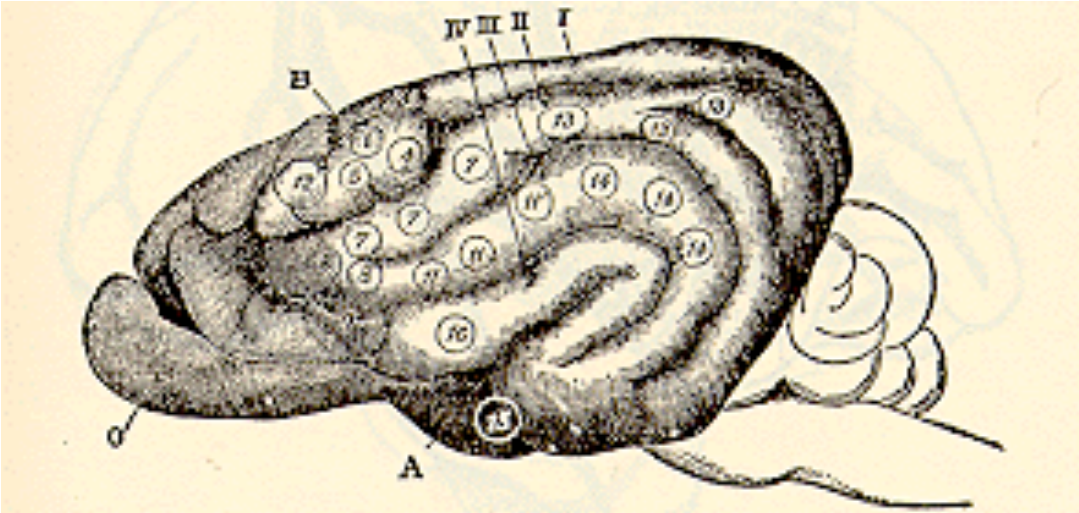
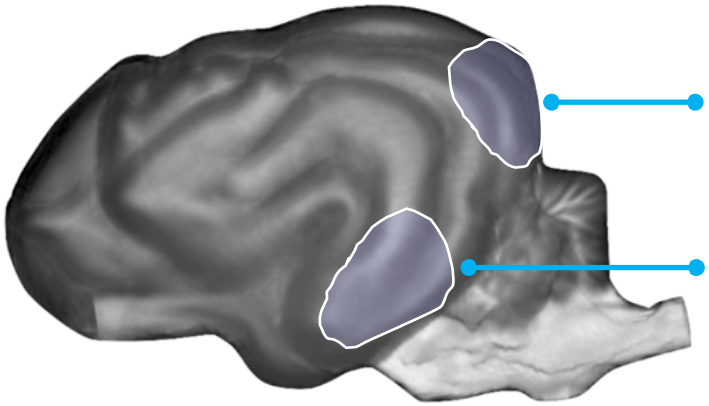


FIG. 5.—Left Hemisphere of Dog's Brain, after Ferrier. *A*, the fissure of Sylvius. *B*, the crucial sulcus. *O*, the olfactory bulb. *I*, *II*, *III*, *IV*, indicate the first, second, third, and fourth external convolutions respectively. (1), (4), and (5) are on the sigmoid gyrus.

Ferrier (1870)

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.

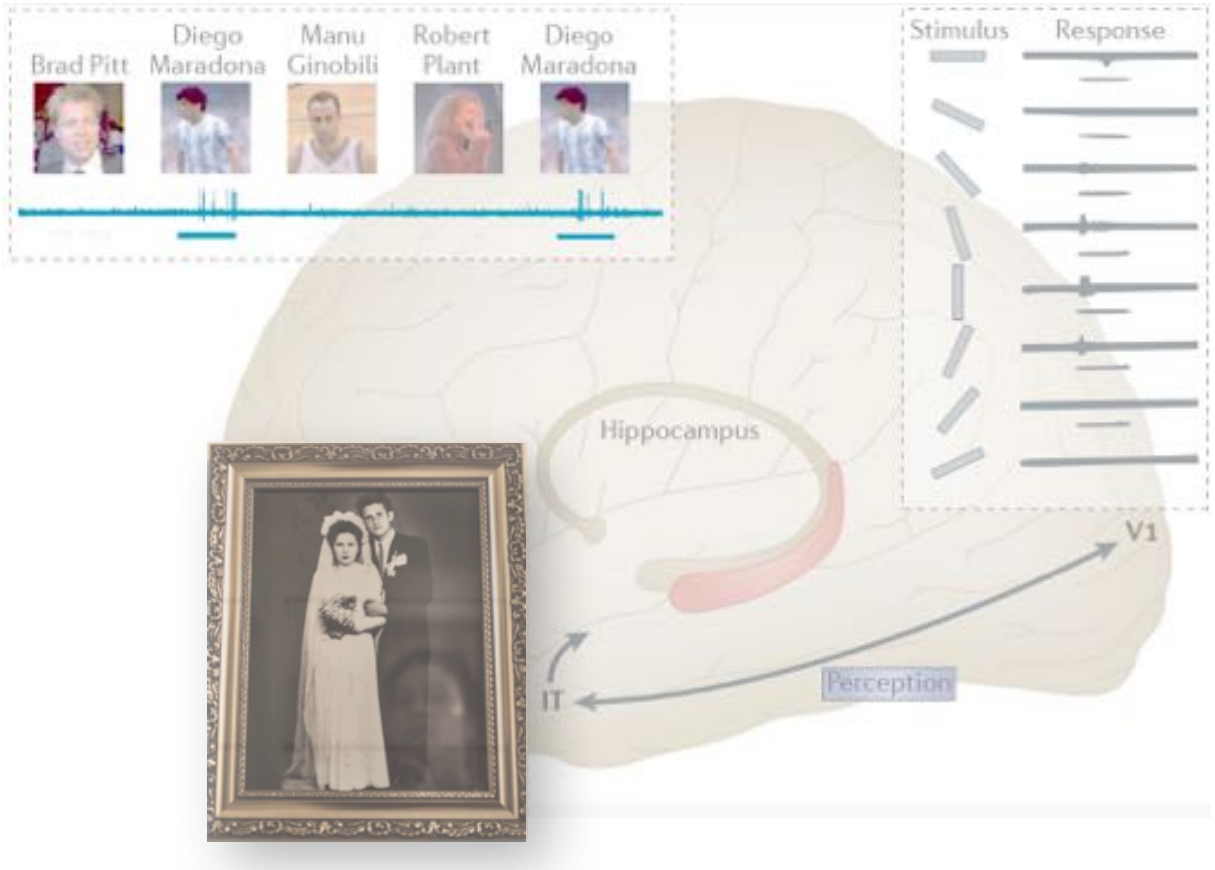
- intracortical processing transforms mere physical data into the perception of things that are "out there" (Whitfield, p. 146) in the world.

more on Whitfield later in course

Munk (1880)

First to distinguish sensation from perception.

Temporal lobe lesion leads to visual agnosia: loss of visual knowledge
= loss of visual perception



Tatsuji Inouye, 1905

perspectives

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

Mitchell Glickstein and David Whitteridge

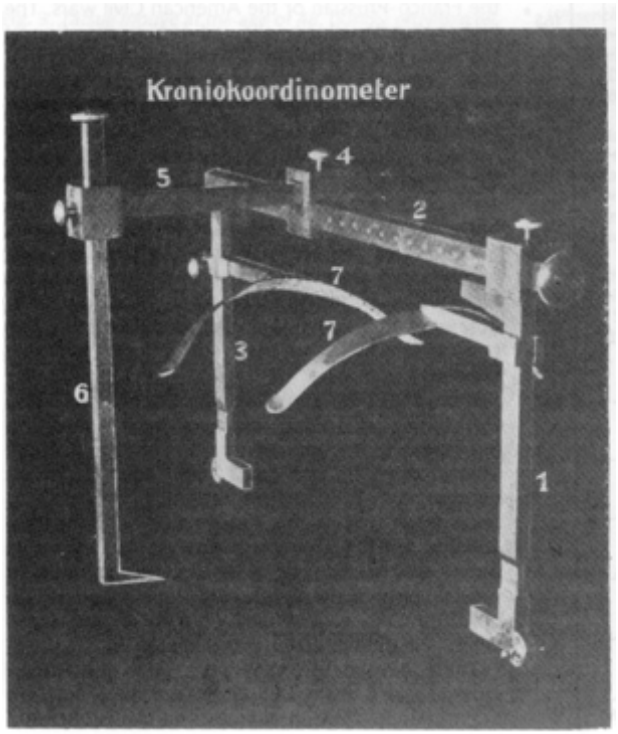

Kraniokoordinometer
1
2
3
4
5
6
7
7

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

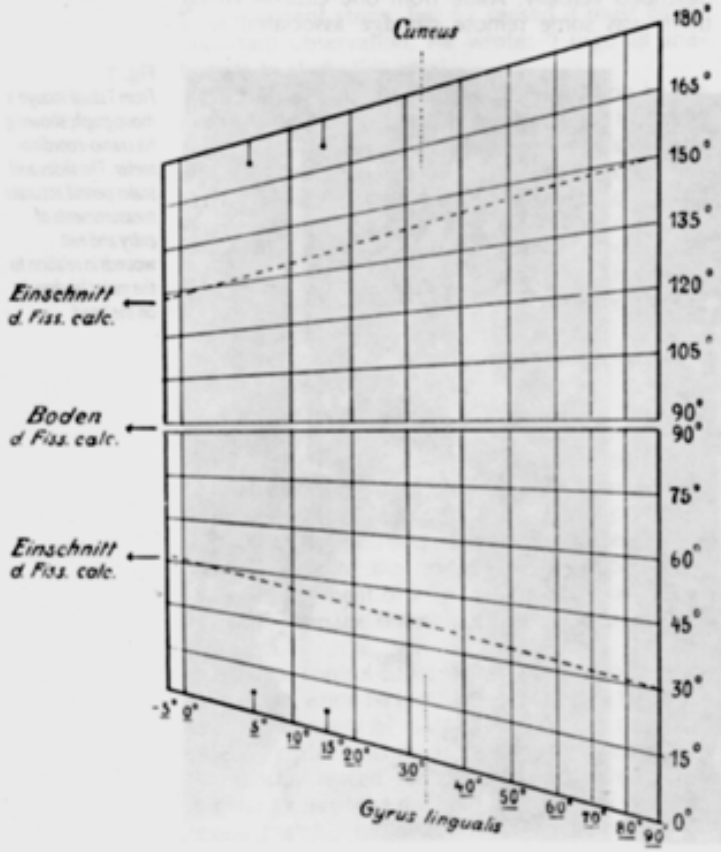
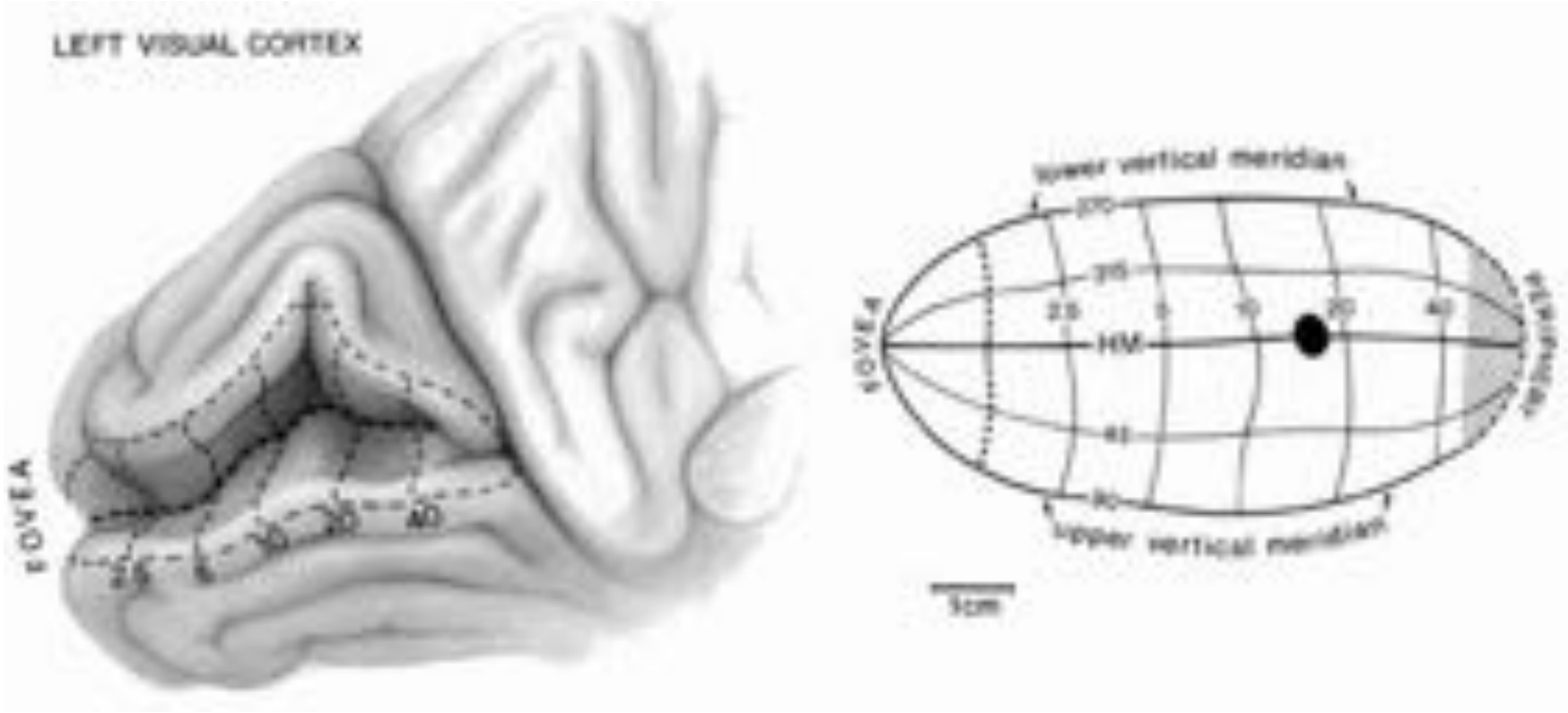


Fig. 2.
Inouye's schema for the projection of the visual fields on the striate cortex.

human visual cortex retinal map by modern methods

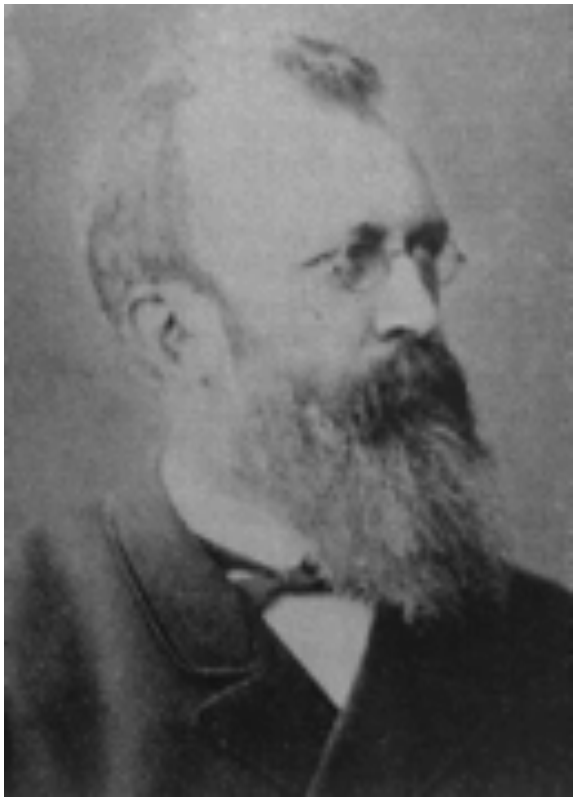


Localization of function

Localization of function by electrical
electrical recording and stimulation

(neurophysiology and neurosurgery)

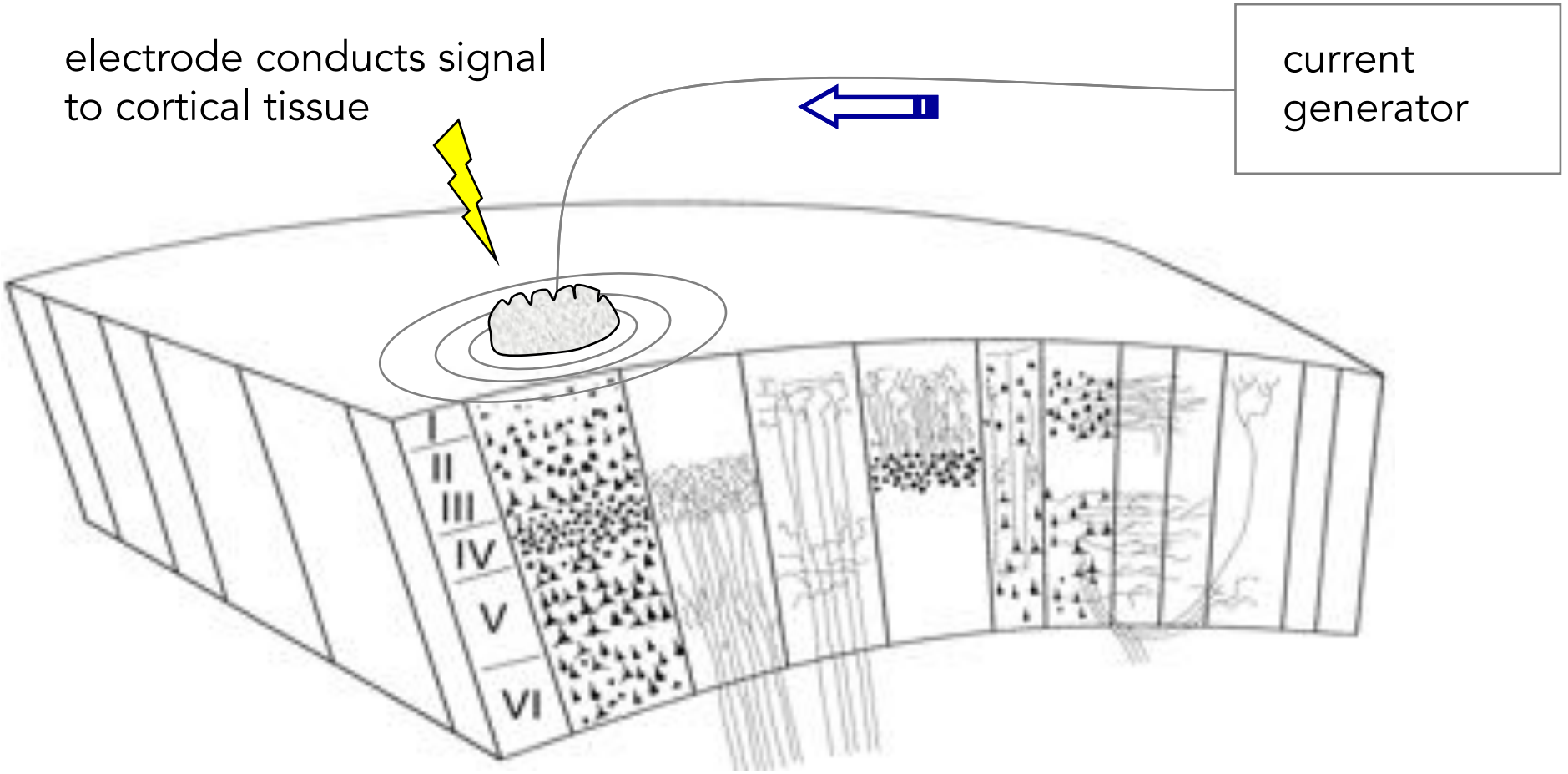
the method of targeted and
restricted electrical stimulation...



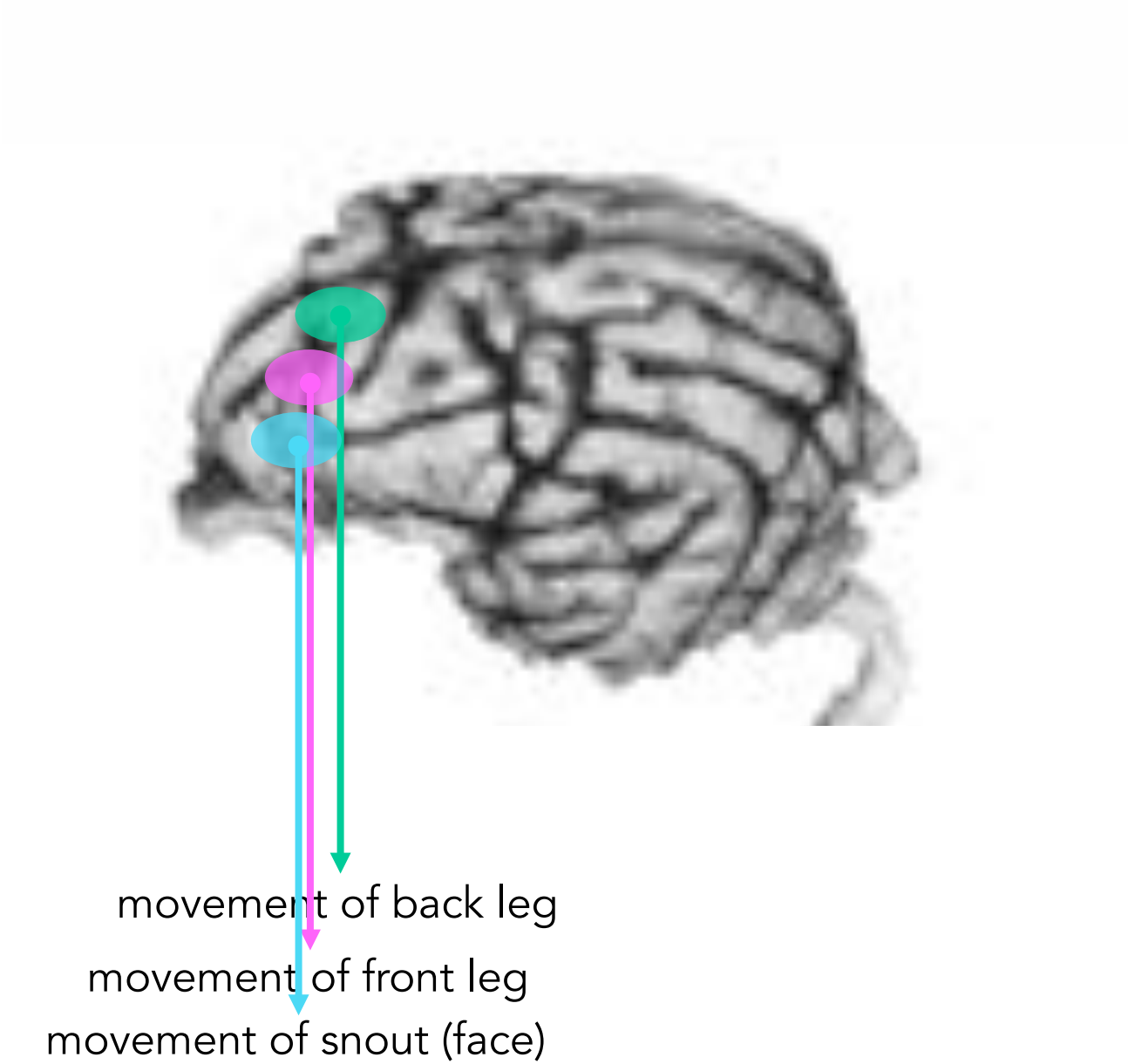
Hitzig

Fritsch

electrical stimulus

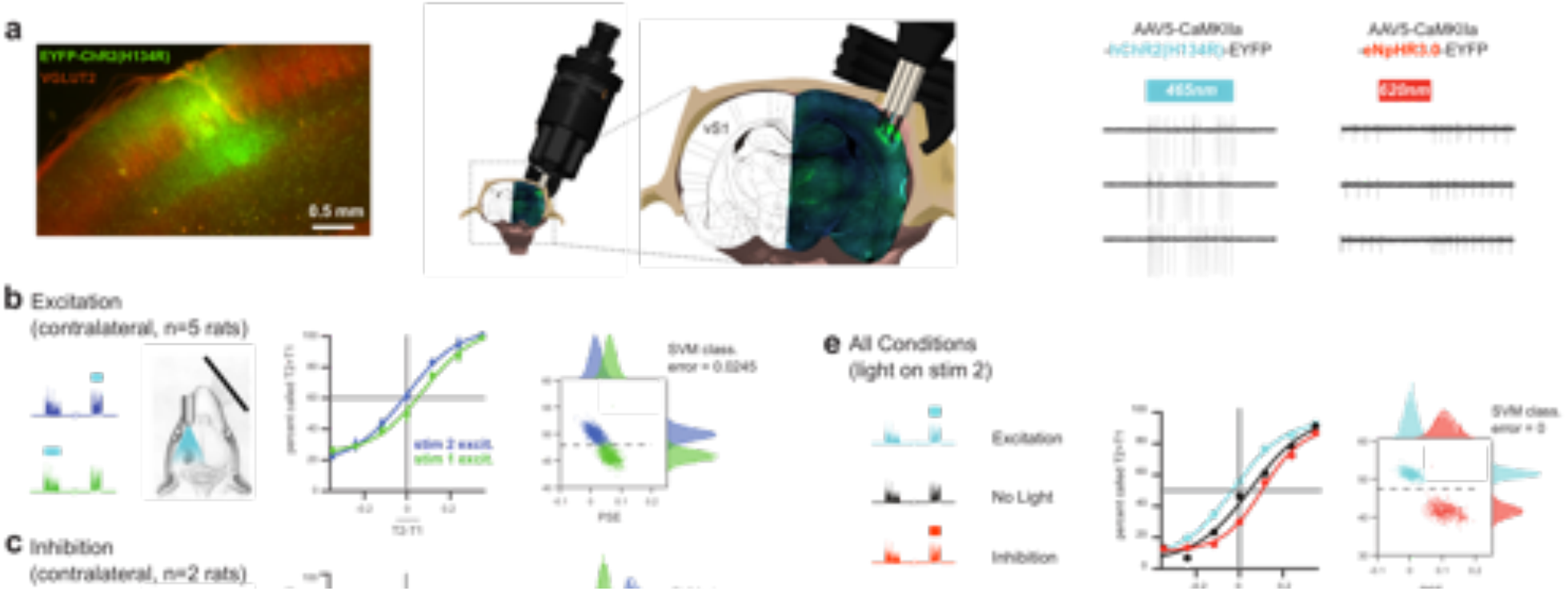


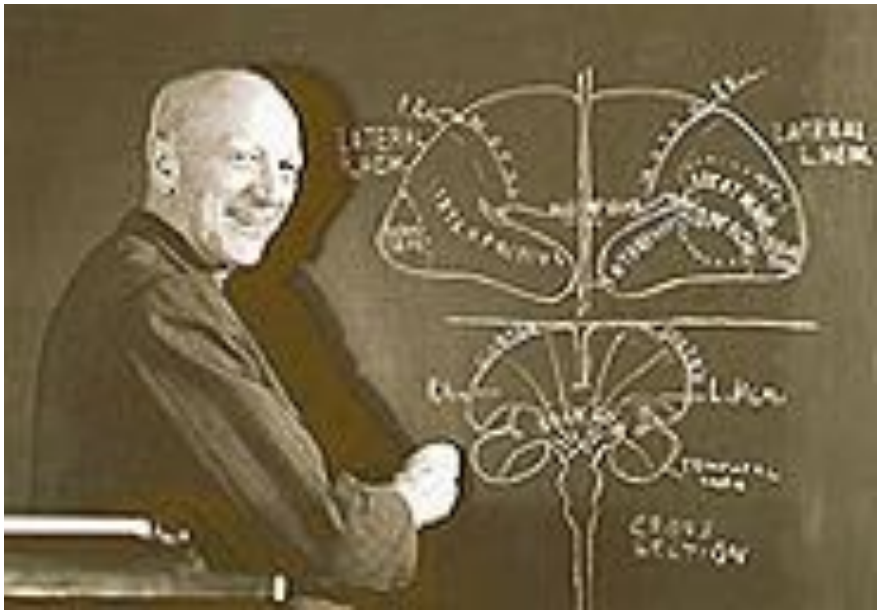
…led to the detection of areas with specific motor functions



Today's methods

Sebastian Reinartz
SISSA postdoc





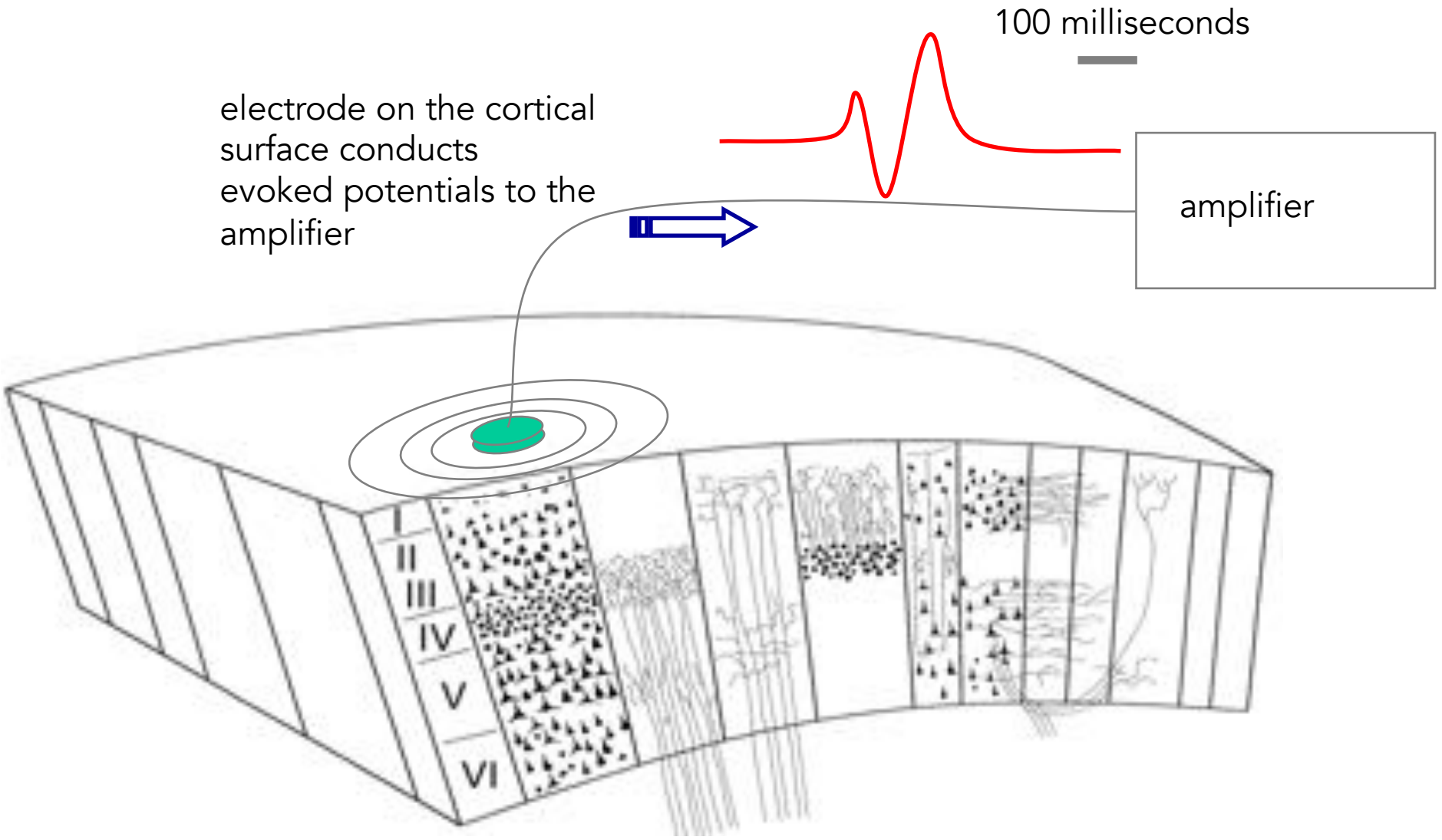
Wilder Penfield

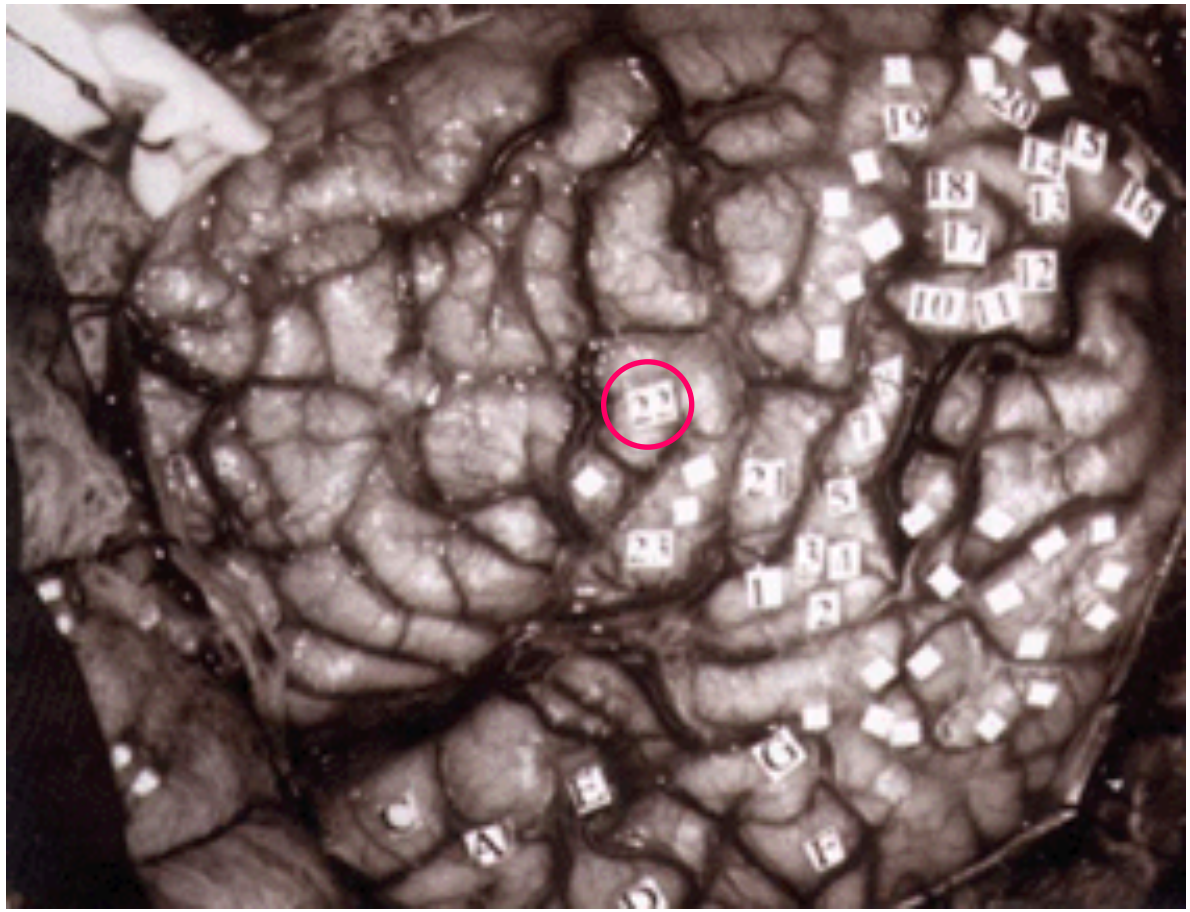
physiological exploration of the human cerebral cortex

(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

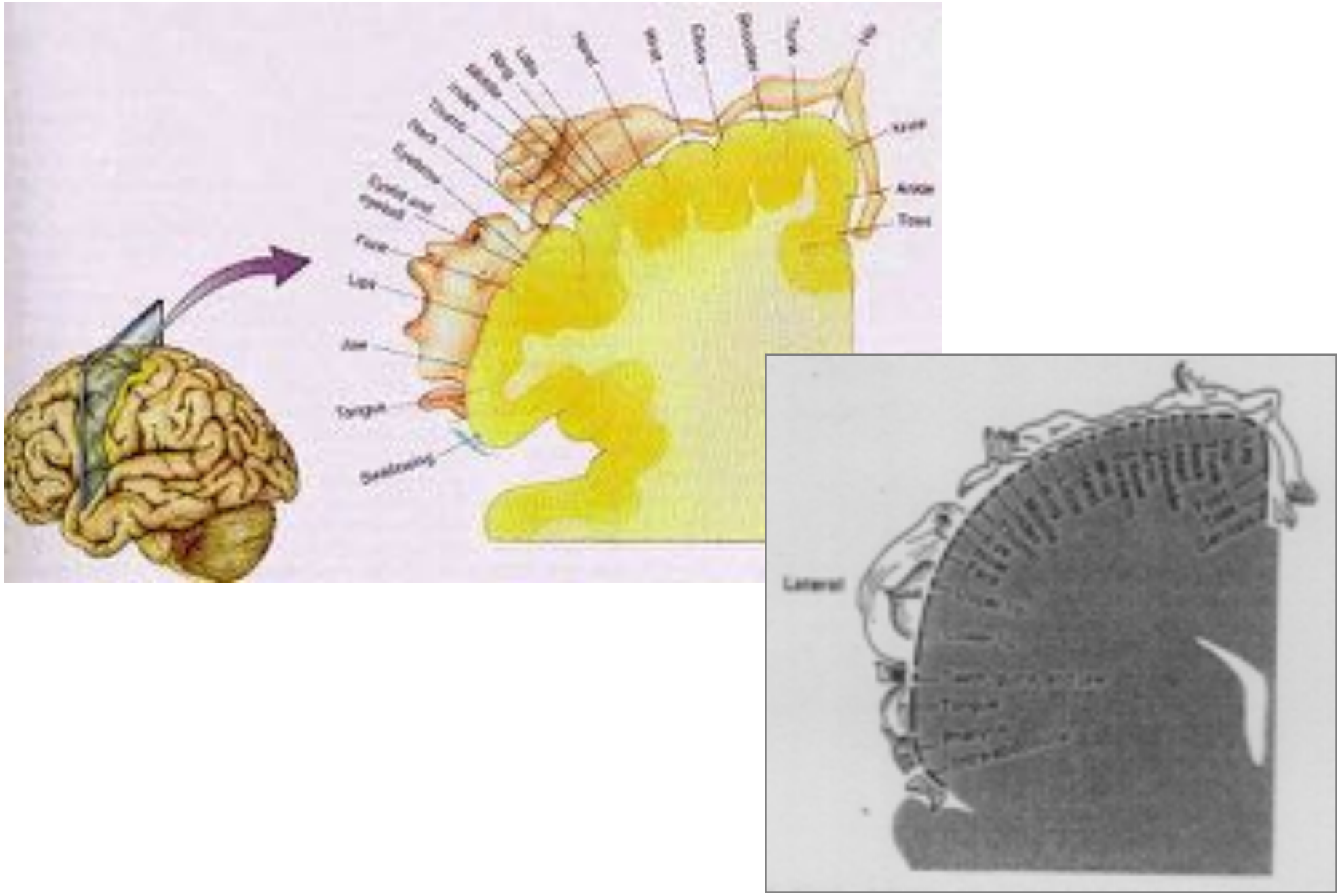


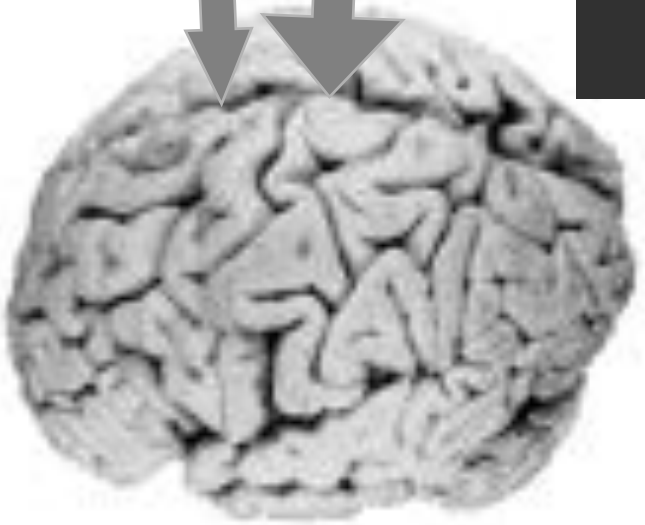


https://www.youtube.com/watch?v=obiARnsKUAo

2:40 --Singing interrupted by cortical stimulation

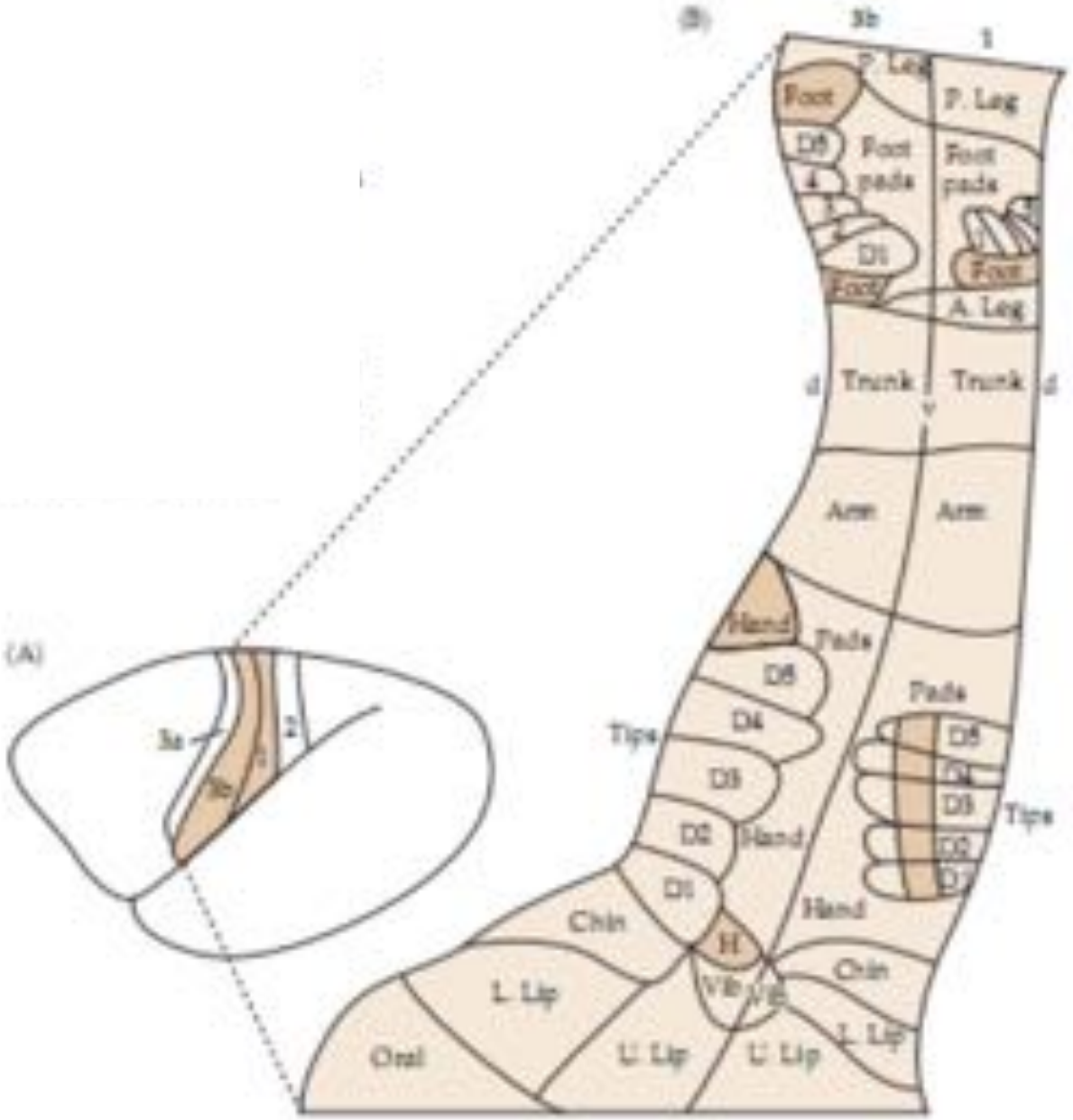
the motor and the sensory maps in the human

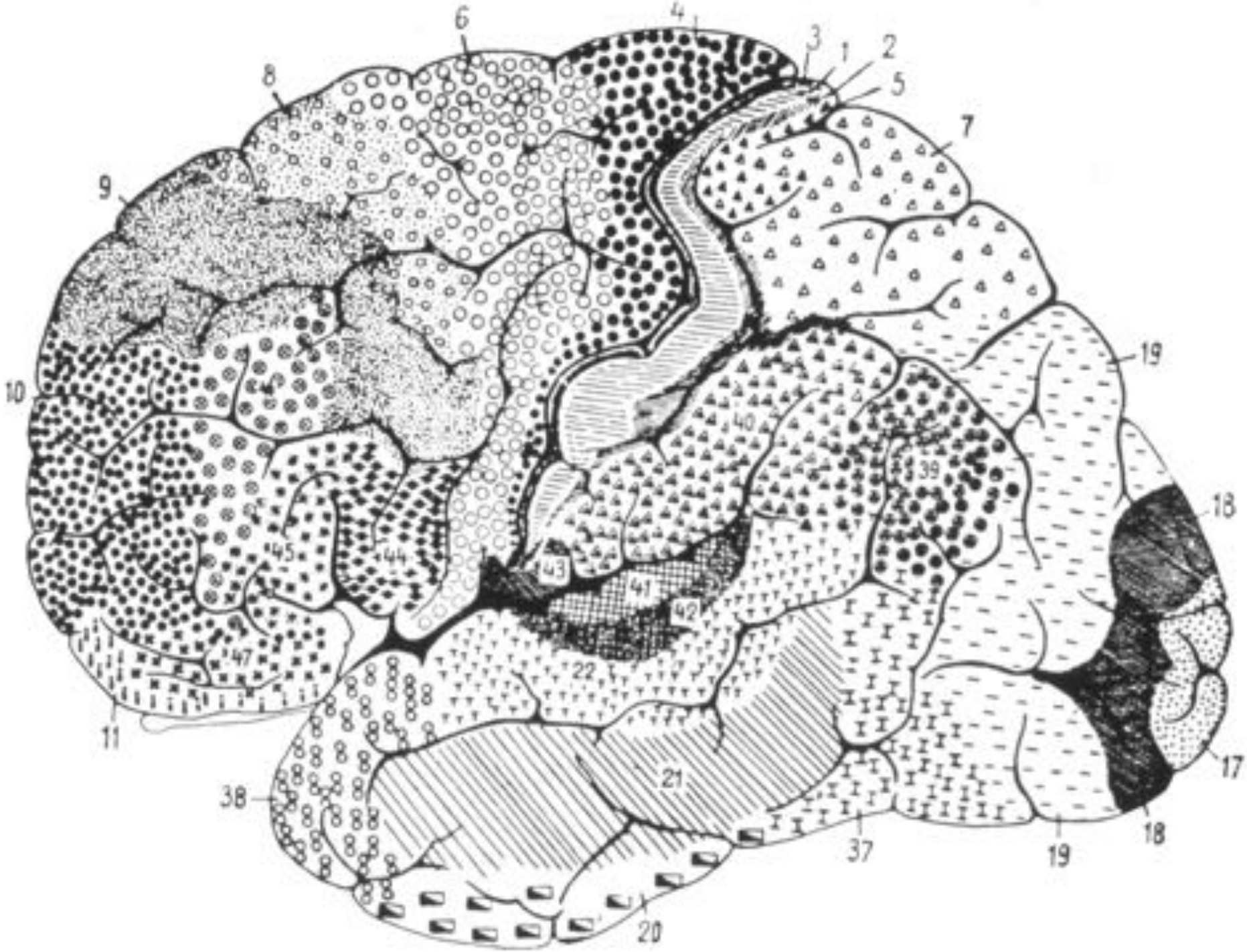




Human

The ancients thought about hands


(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


6
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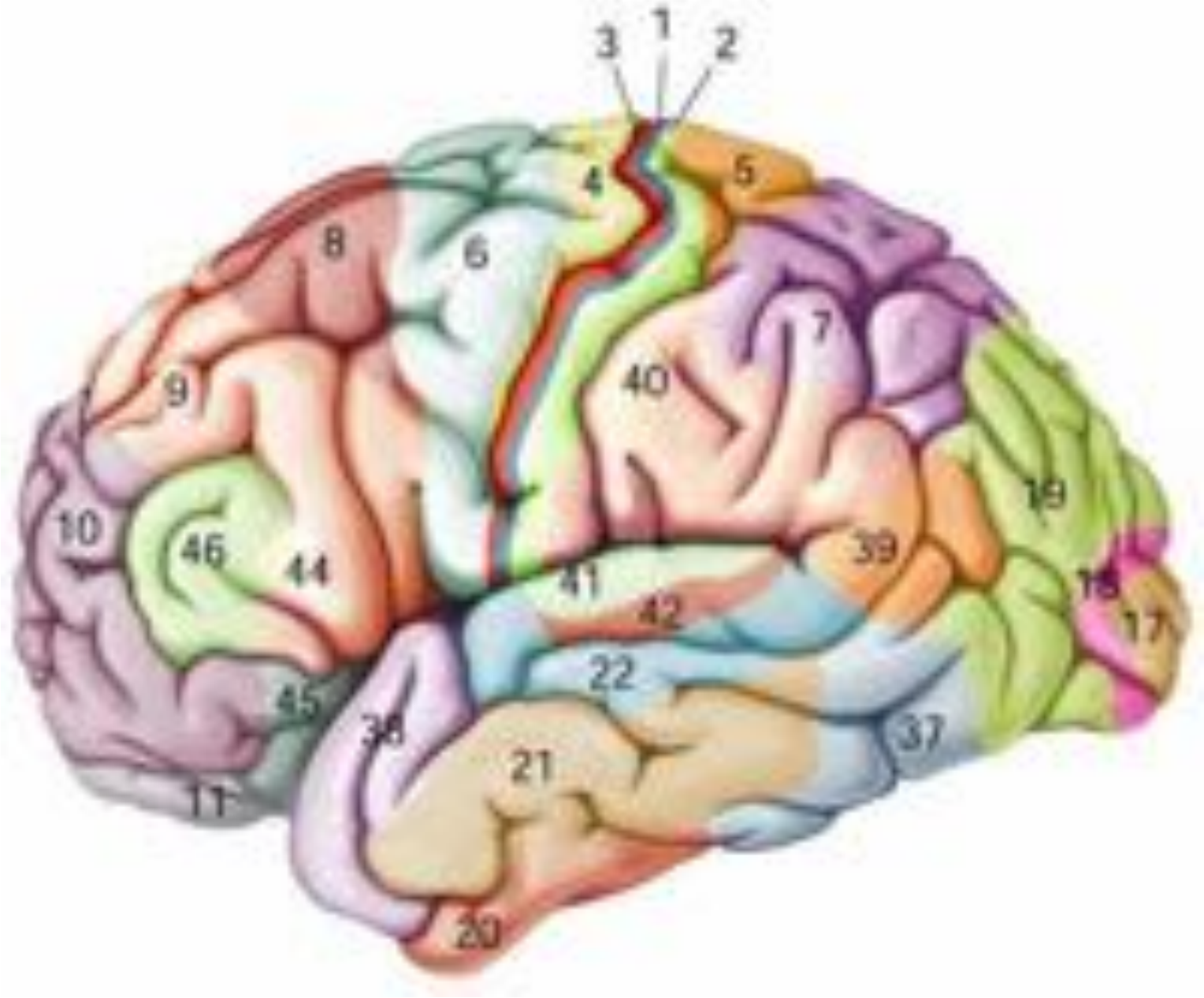
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11
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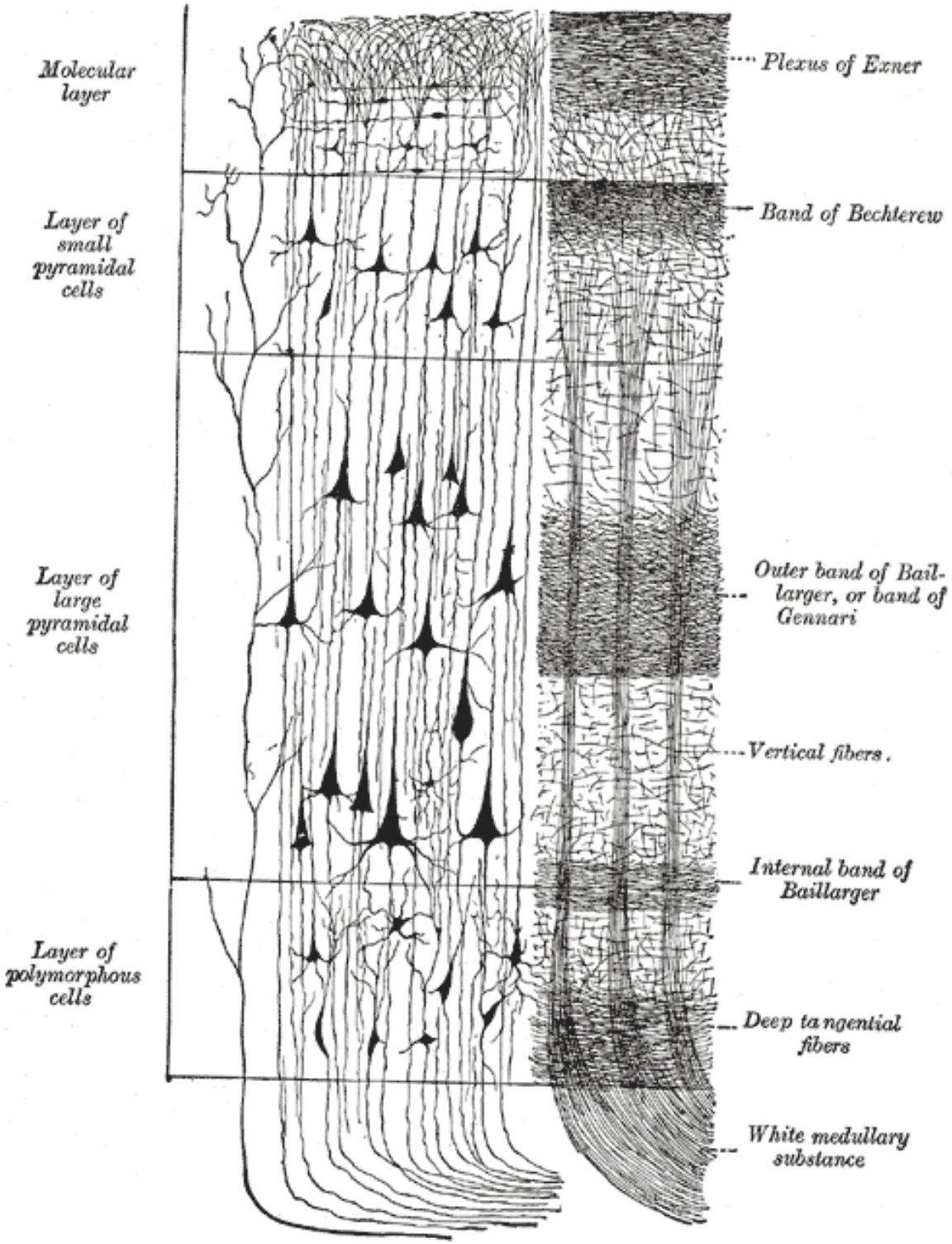

Molecular layer
Layer of small pyramidal cells
Layer of large pyramidal cells
Layer of polymorphous cells
Plexus of Exner
Band of Bechterew
Outer band of Baillarger, or band of Gennari
Vertical fibers.
Internal band of Baillarger
Deep tangential fibers
White medullary substance

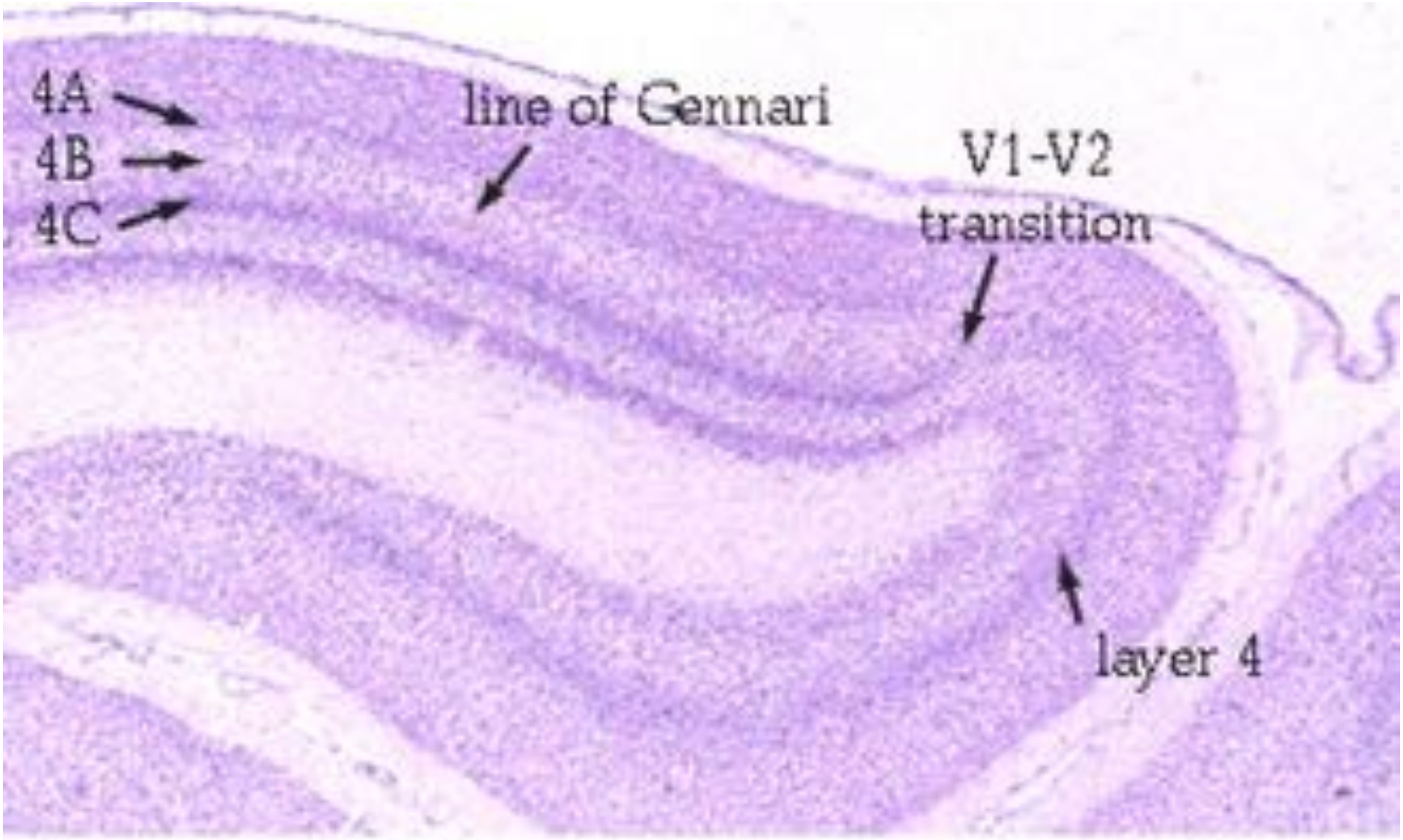
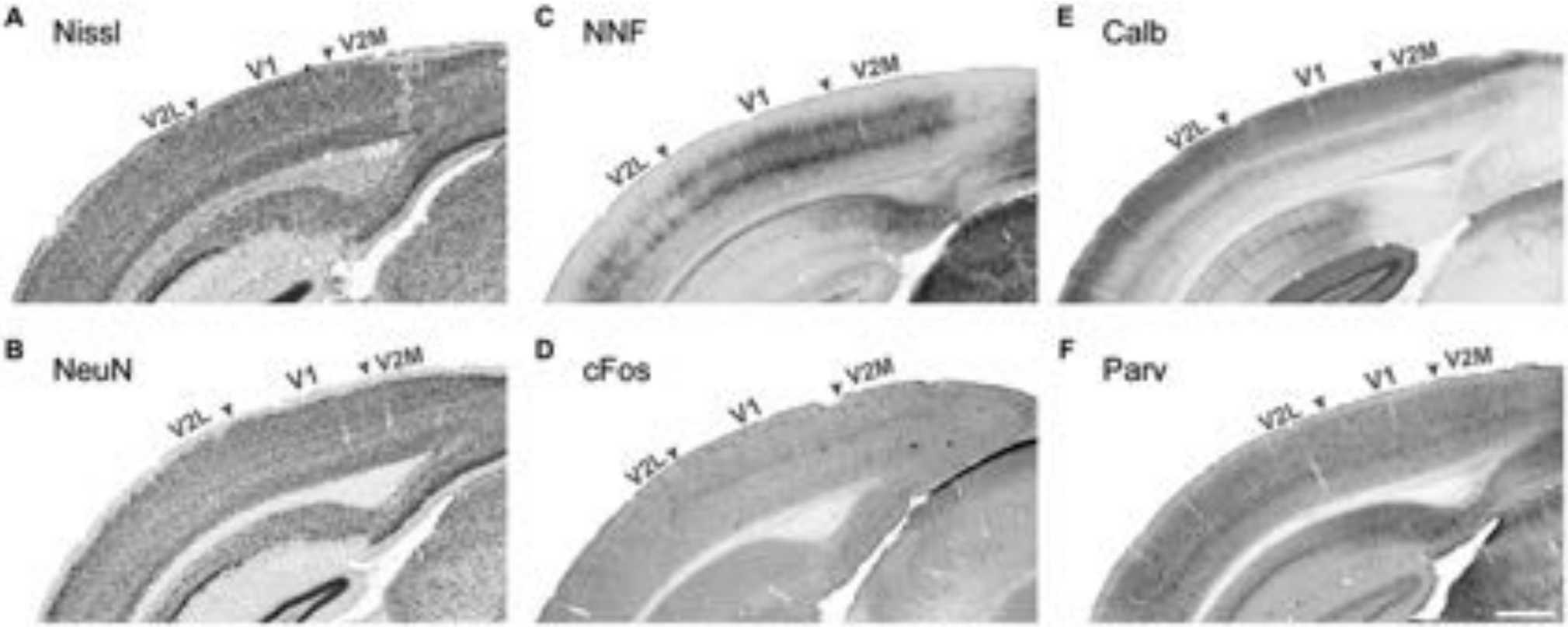
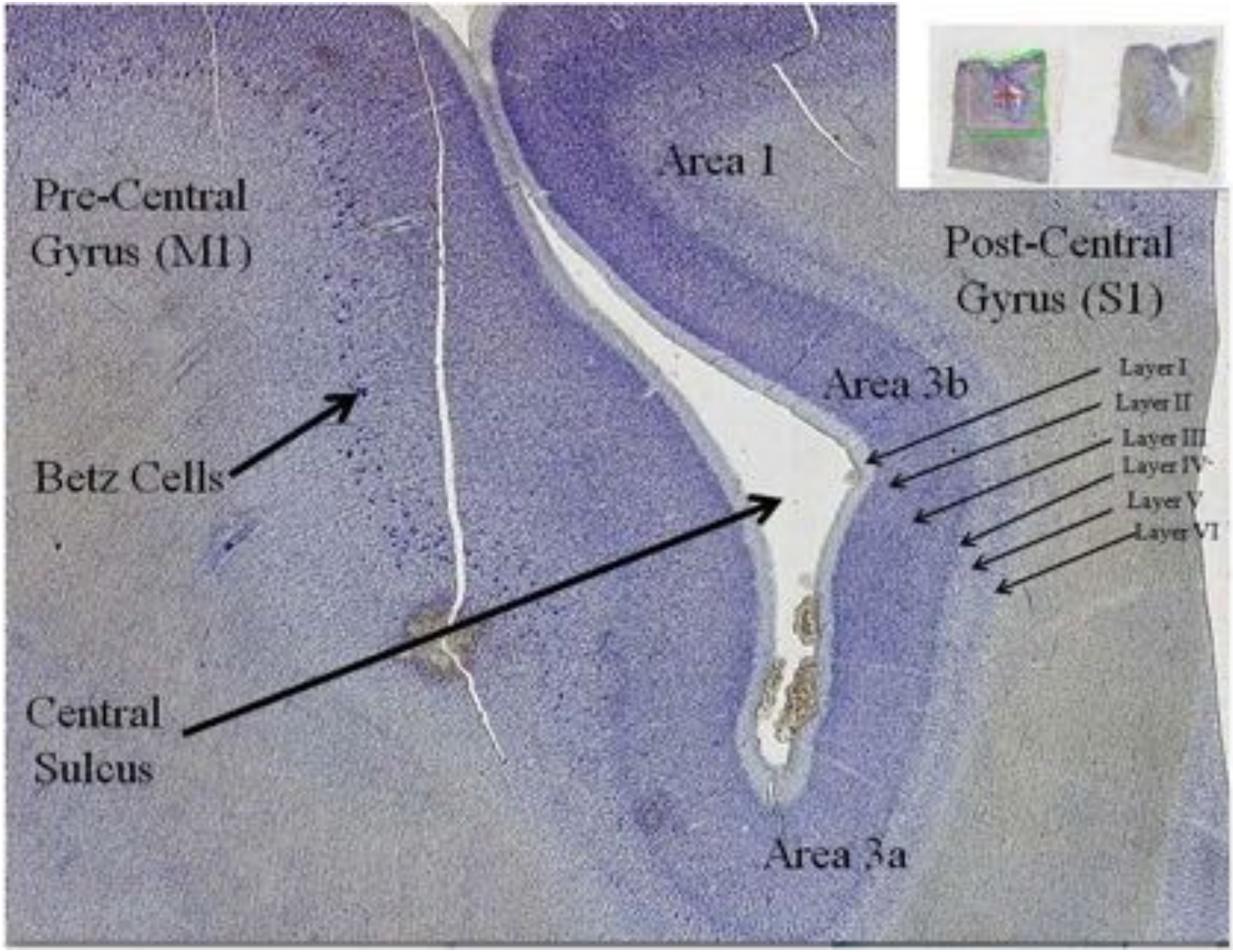


Figure 9. Nissl stained section of the visual cortex to show the border between area 17 (V1) and area 18 (V2).


A
Nissl
V2L
V1
V2M
C
NNF
V2L
V1
V2M
E
Calb
V2L
V1
V2M
B
NeuN
V2L
V1
V2M
D
cFos
V2L
V1
V2M
F
Parv
V2L
V1
V2M

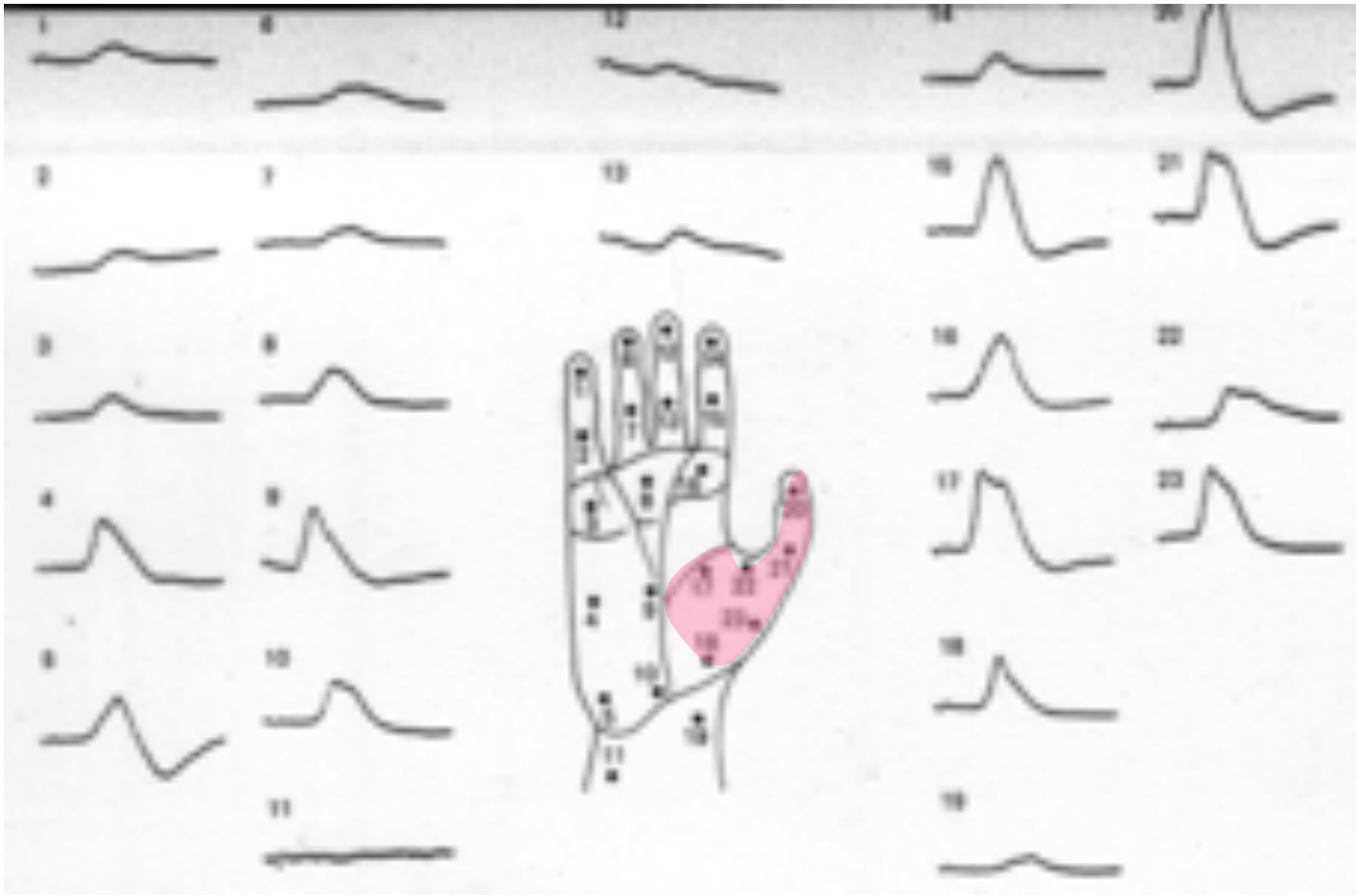

Pre-Central
Gyrus (M1)
Area 1
Post-Central
Gyrus (S1)
Area 3b
Layer I
Layer II
Layer III
Layer IV
Layer V
Layer VI
Betz Cells
Central
Sulcus
Area 3a

experimental basic research proceeds in parallel

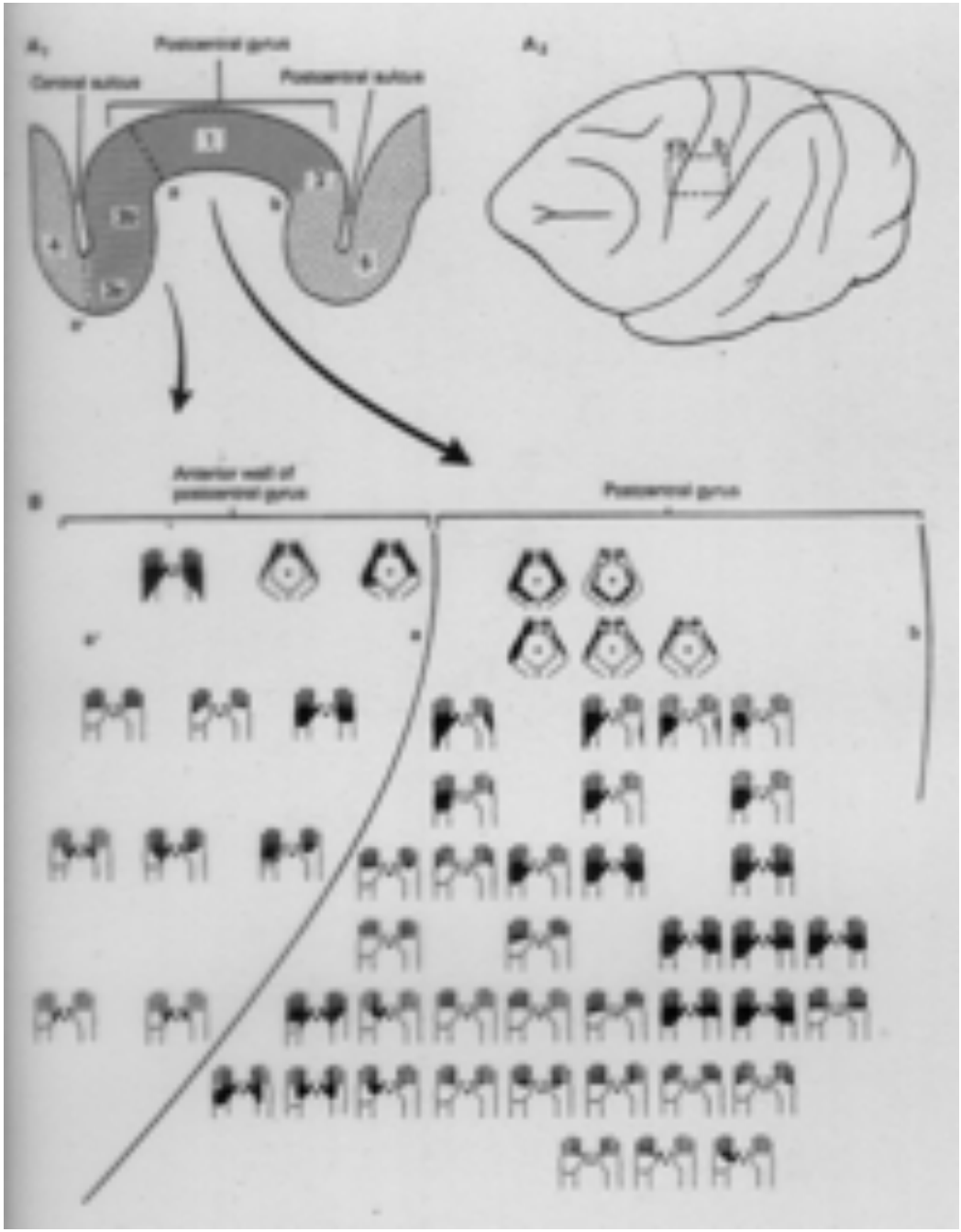
neurophysiology laboratory, 1930s

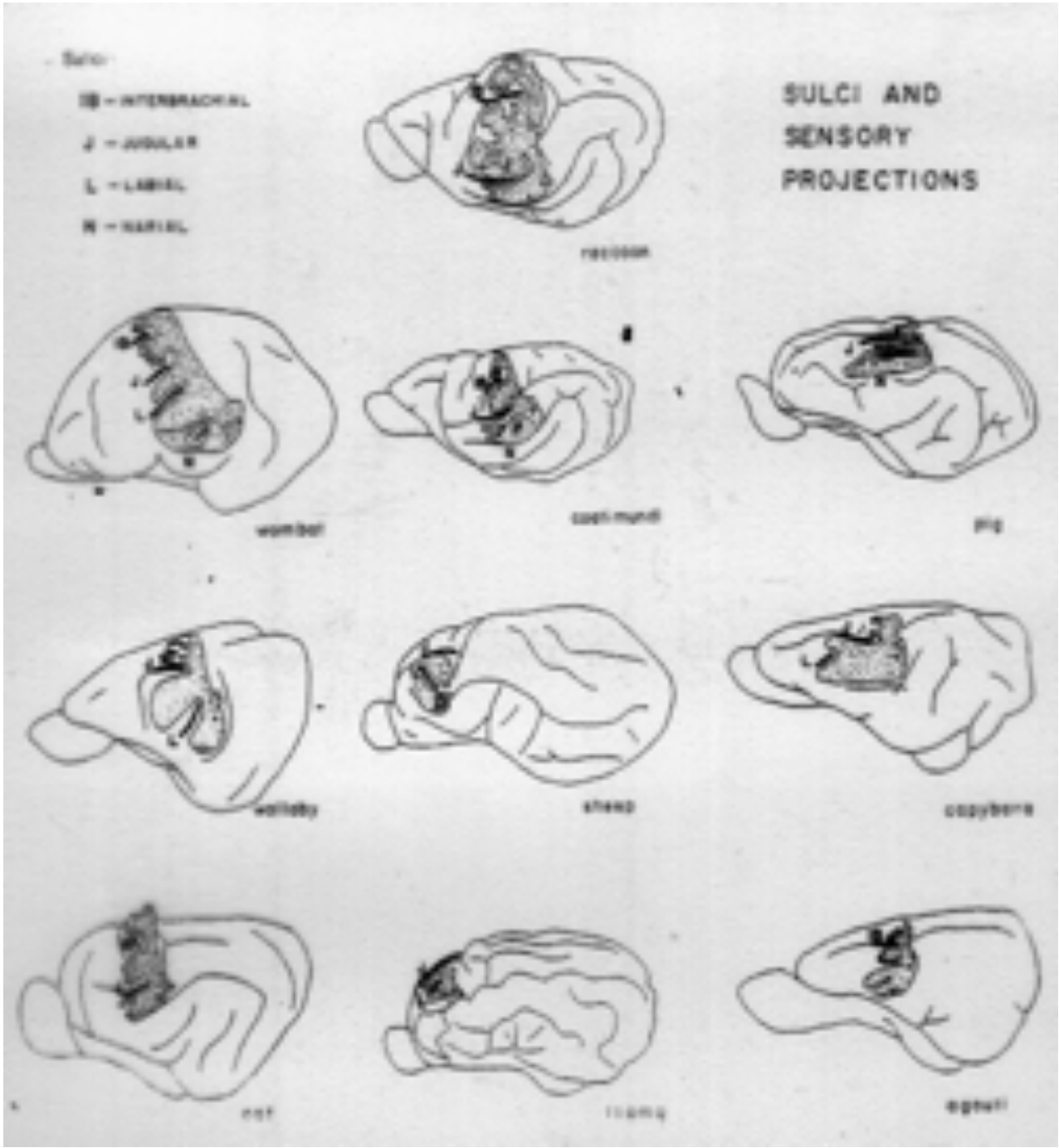
Clinton Woolsey
University of Wisconsin

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

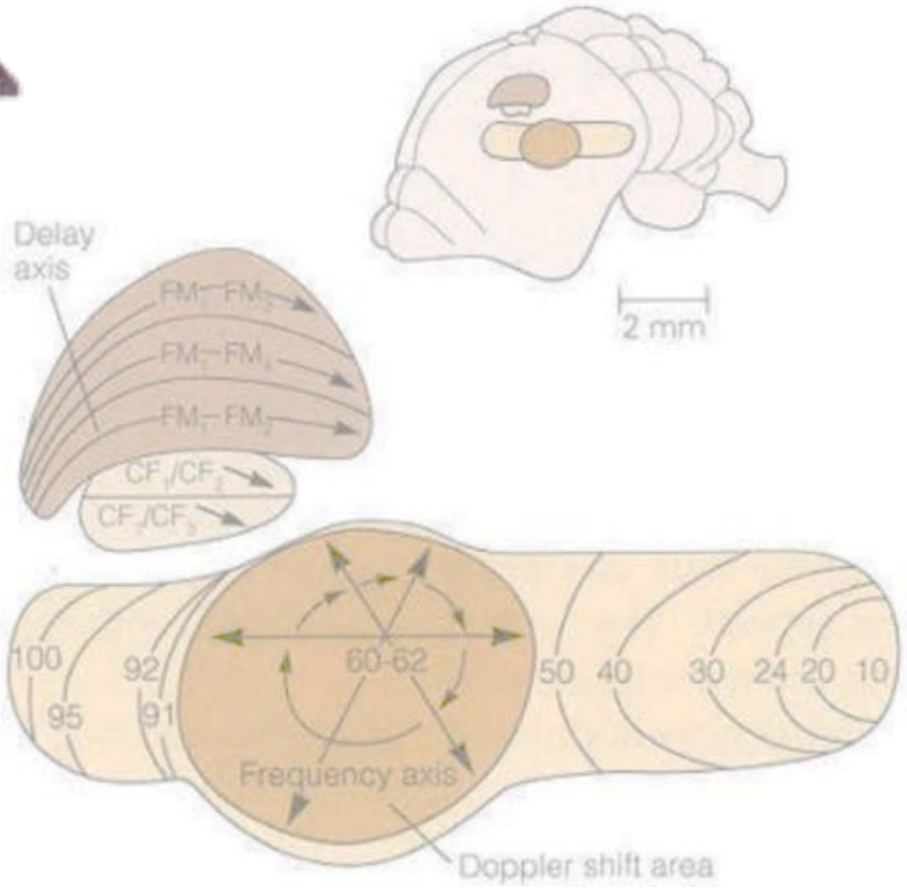


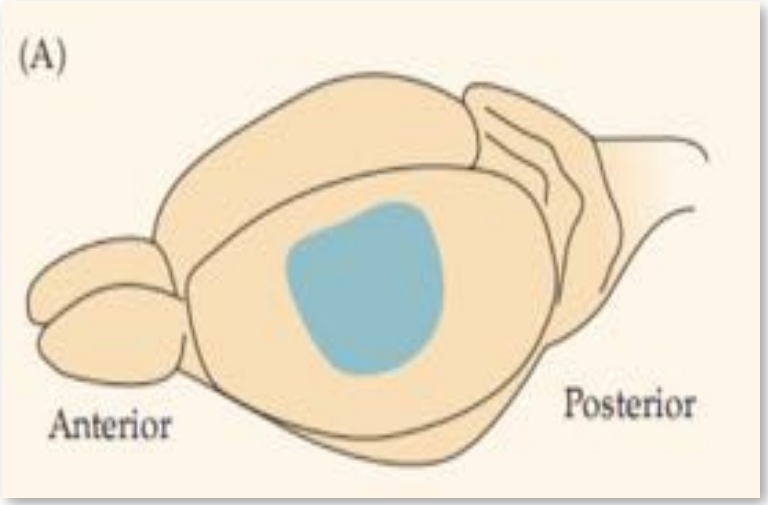
Woolsey's evoked potential mapping:
the skin area projecting to a single cortical site

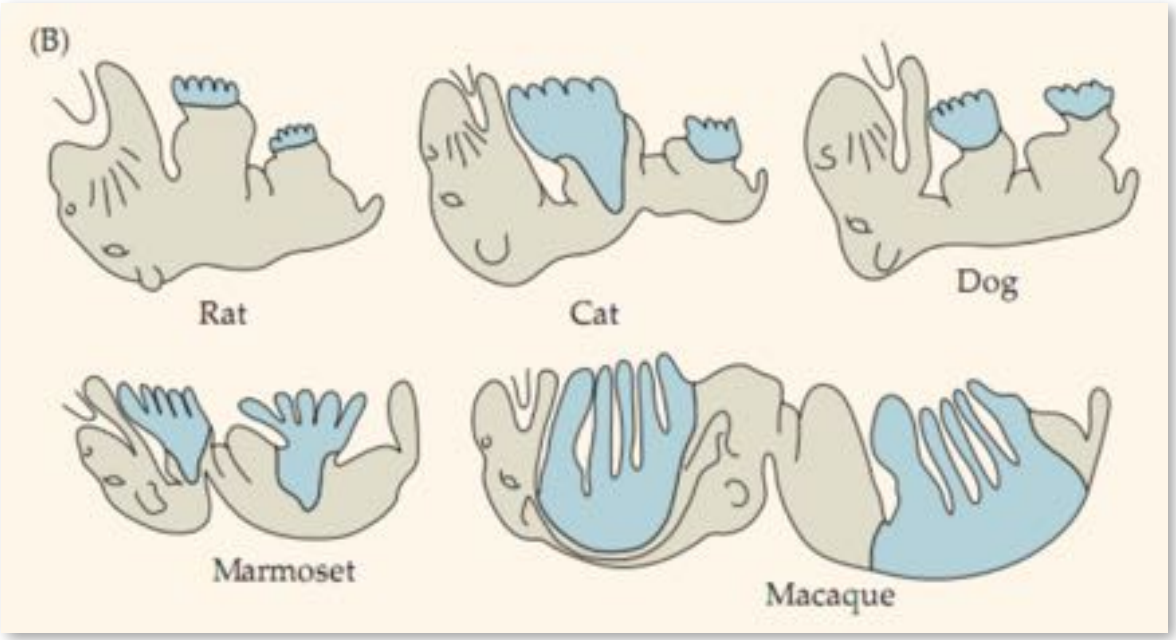

A1
Postcentral gyrus
Central sulcus
Postcentral sulcus
A2
B
Anterior wall of postcentral gyrus
Postcentral gyrus


SULCI AND
SENSORY
PROJECTIONS

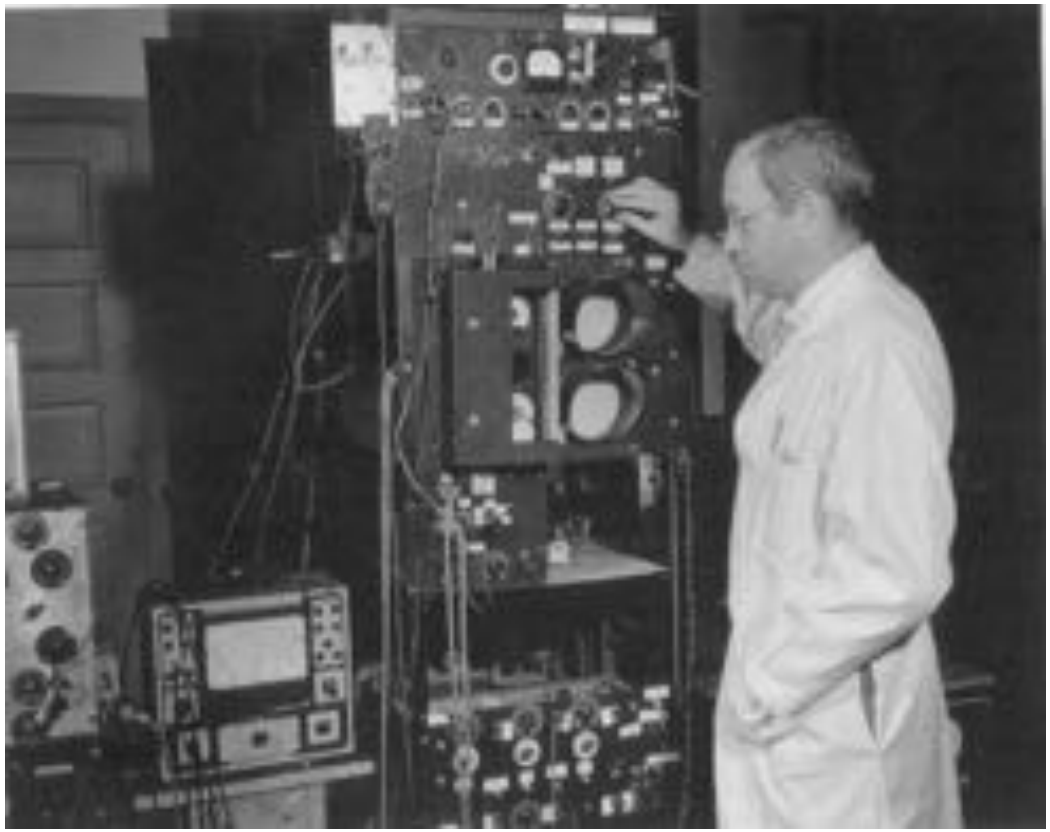
bat auditory cortex





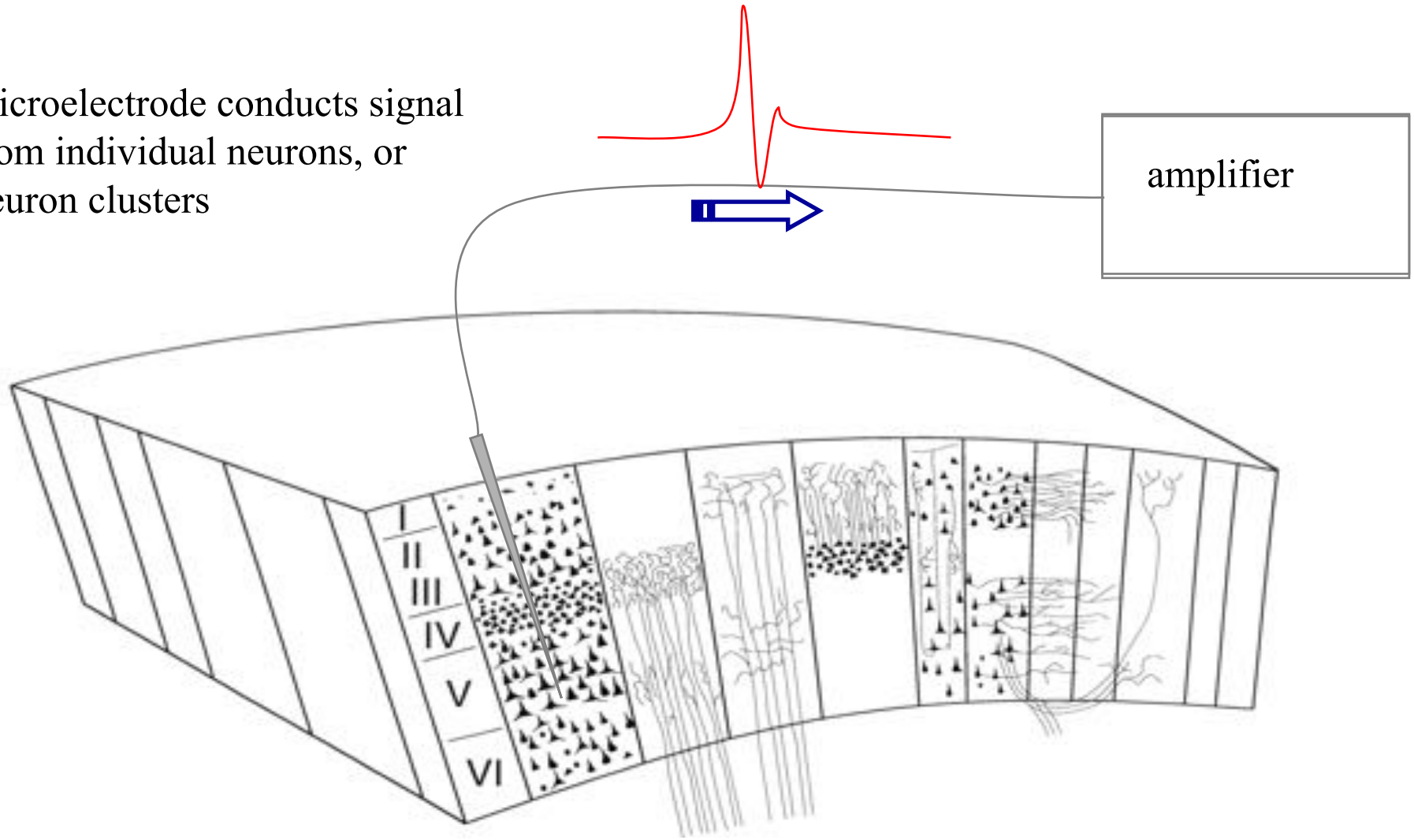


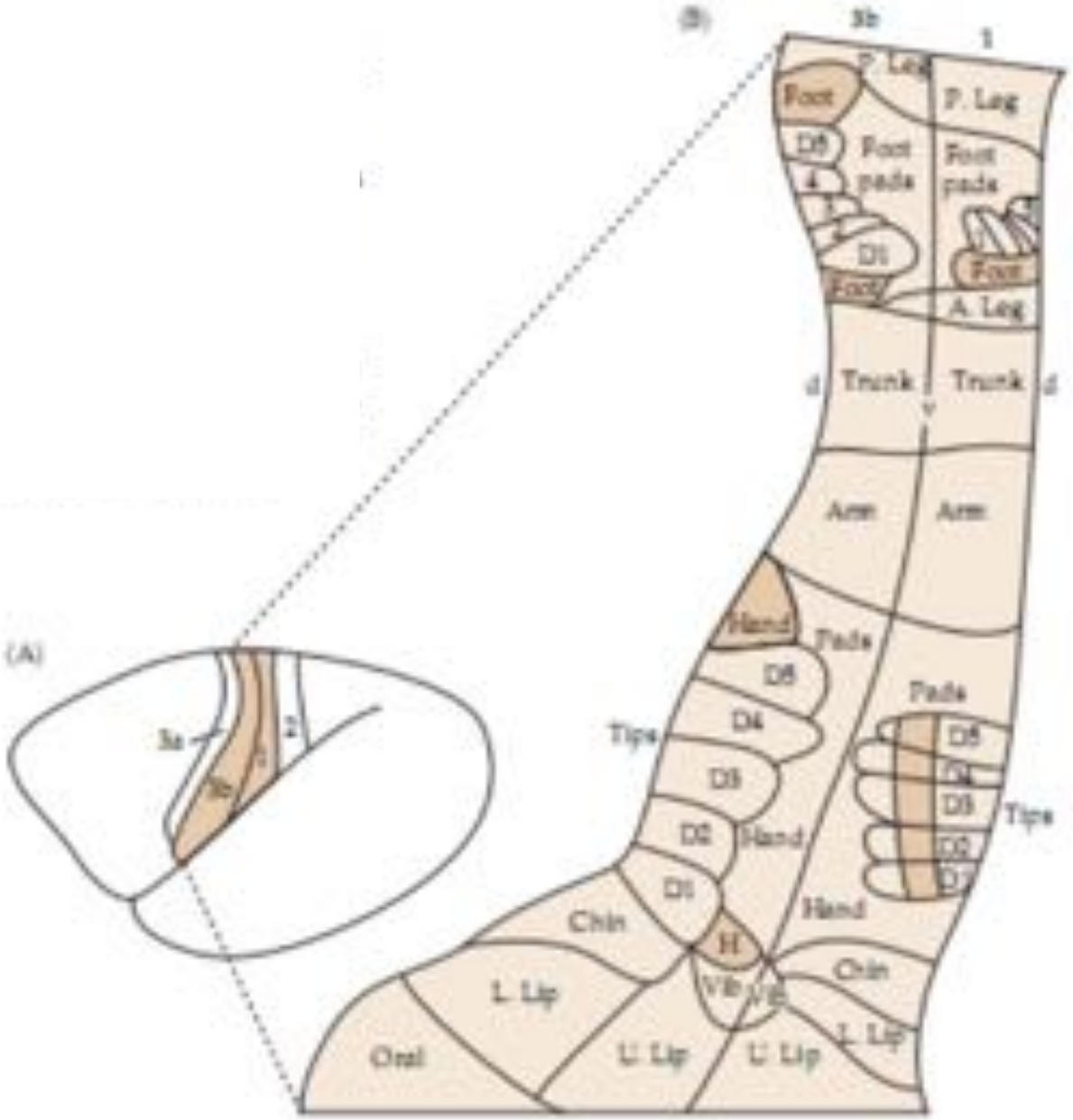
- expansion of the most valuable sensory modality
- expansion of the most valuable receptors within a given representation

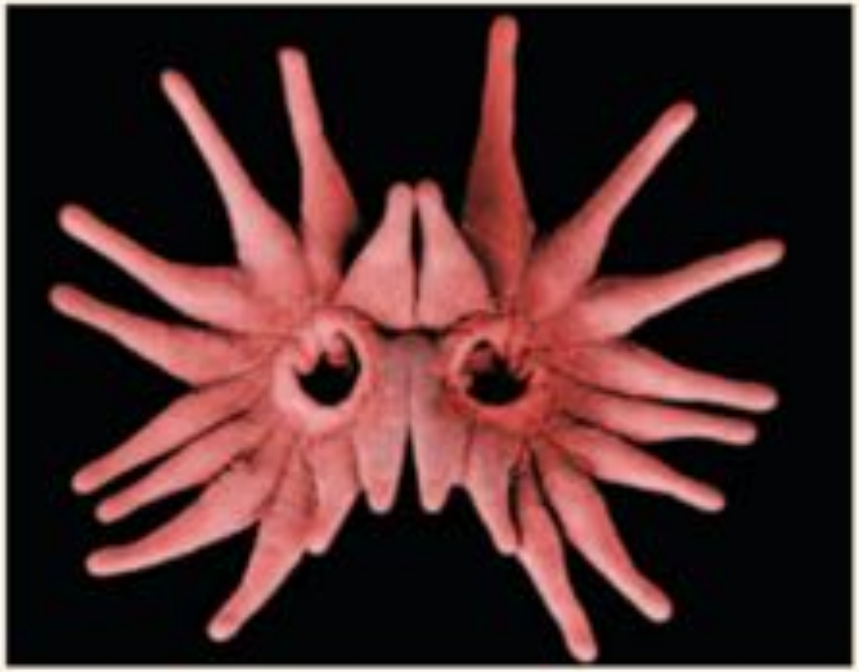


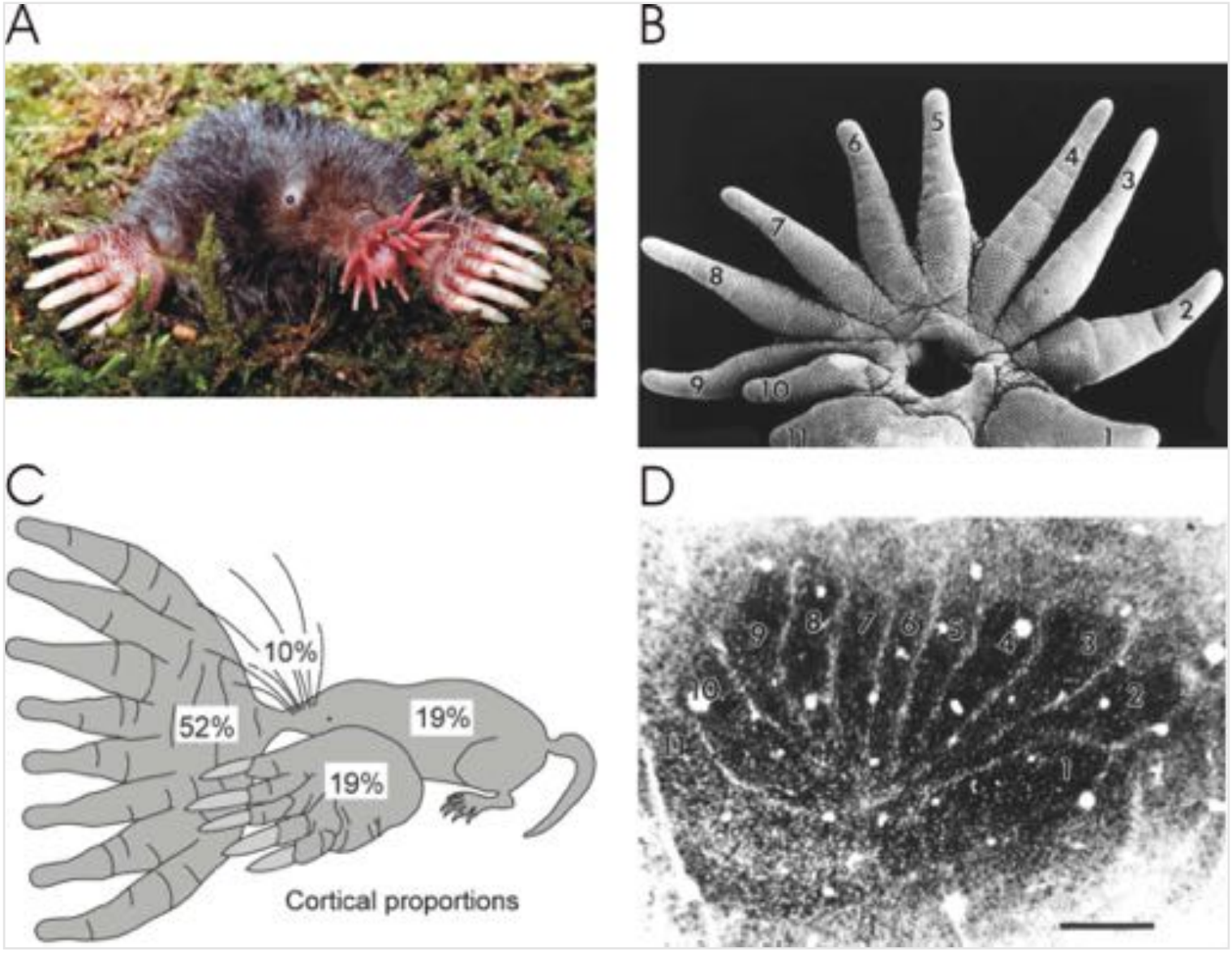
Baltimore (USA), 1955

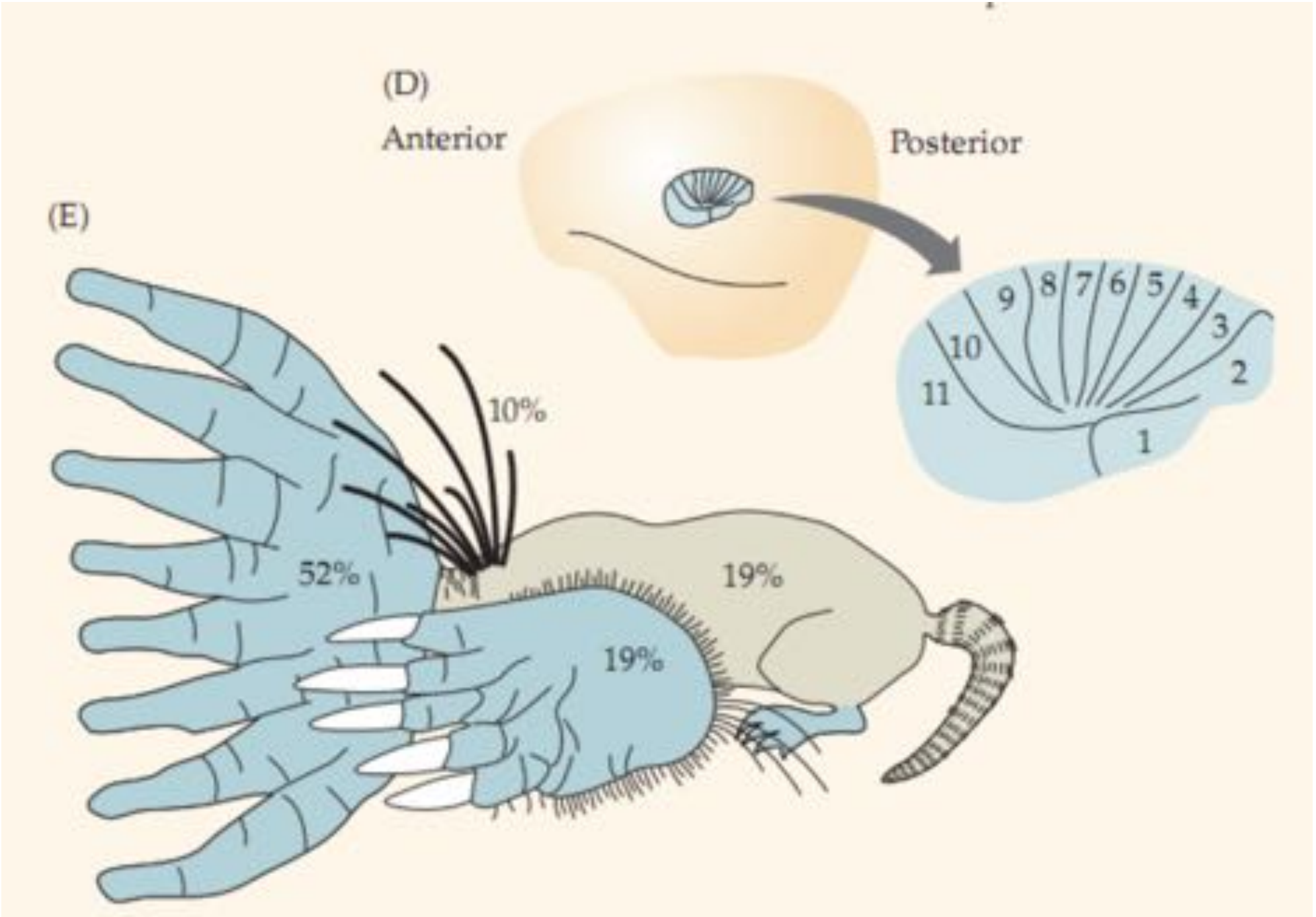
microelectrode conducts signal from individual neurons, or neuron clusters




(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%