Why study an exotic animal?

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Which model system?

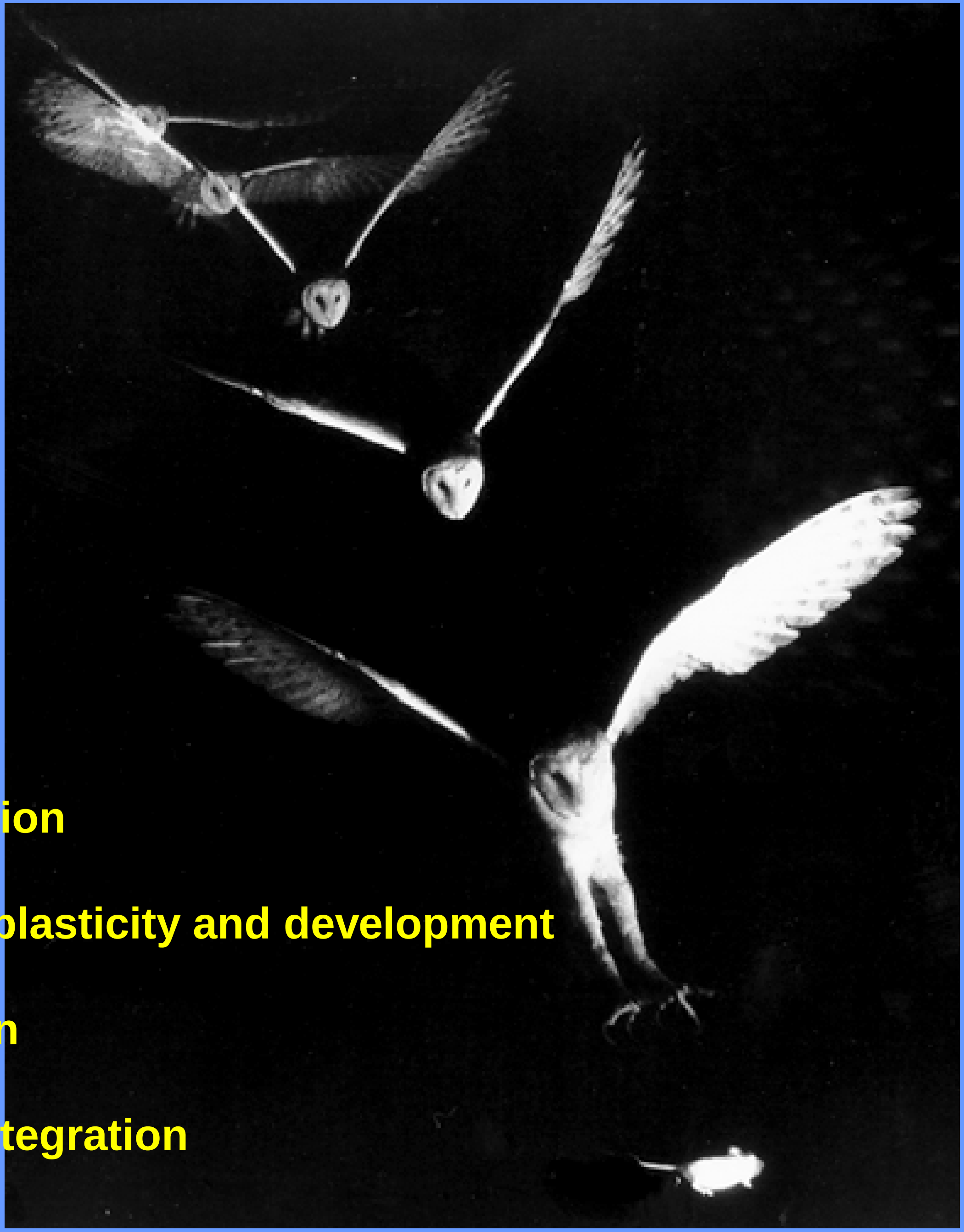
While humans are good for generating hypotheses, animals are good for testing them.

Which animals?

Animals that lend themselves to combined behavioral and neurophysiological work.

Specialists or Generalists?


120 ACA



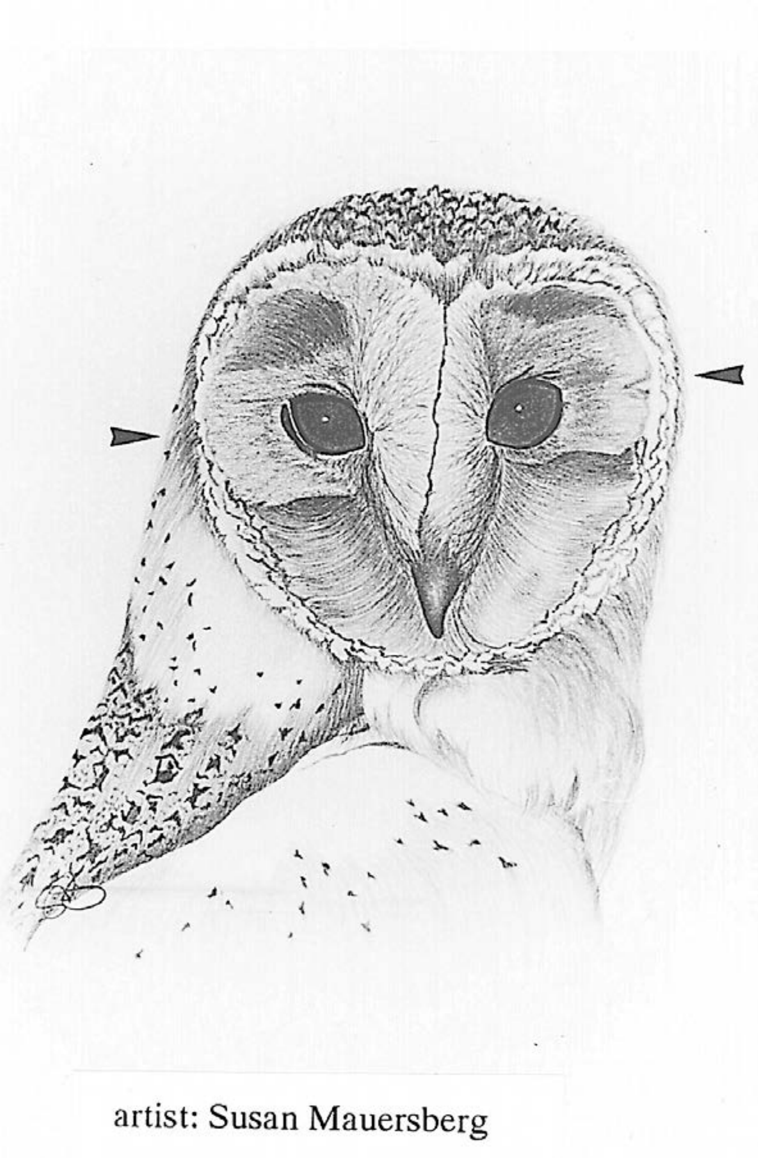
- Sound localization
- Sensory maps plasticity and development
- Spatial attention
- Multisensory integration

Barn owls as model system for sound localization

- Facial ruff serves as a sound amplifier

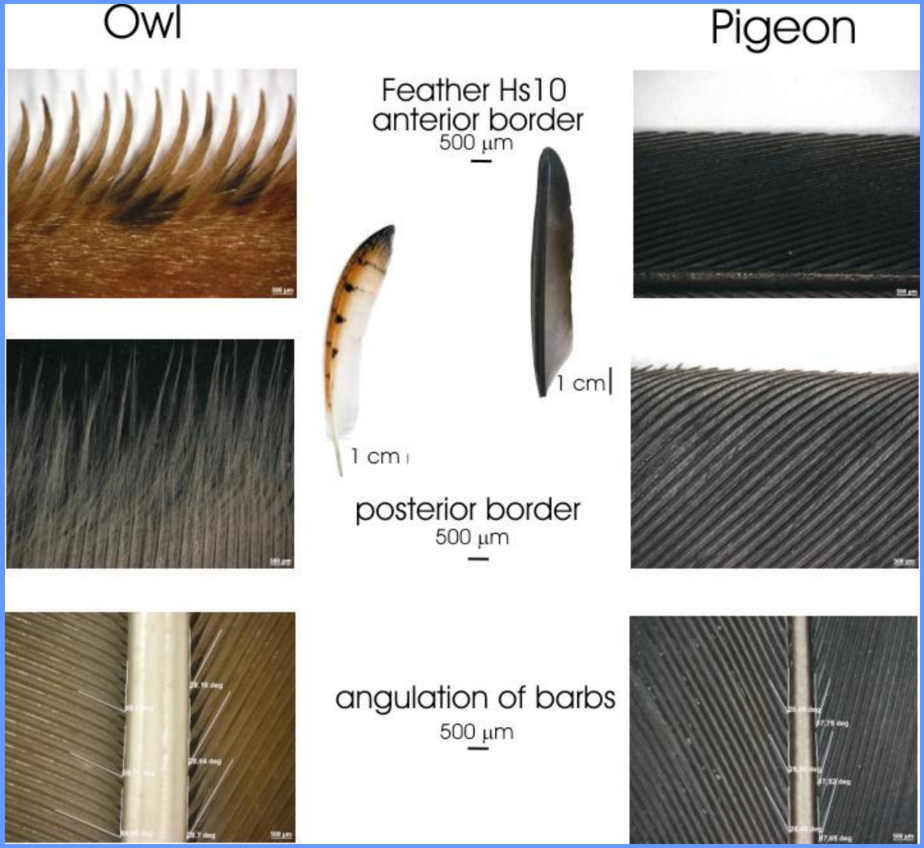
Barn owls as model system for sound localization

- Facial ruff serves as a sound amplifier
- Asymmetric ears allow for an increased spatial resolution in the vertical plane



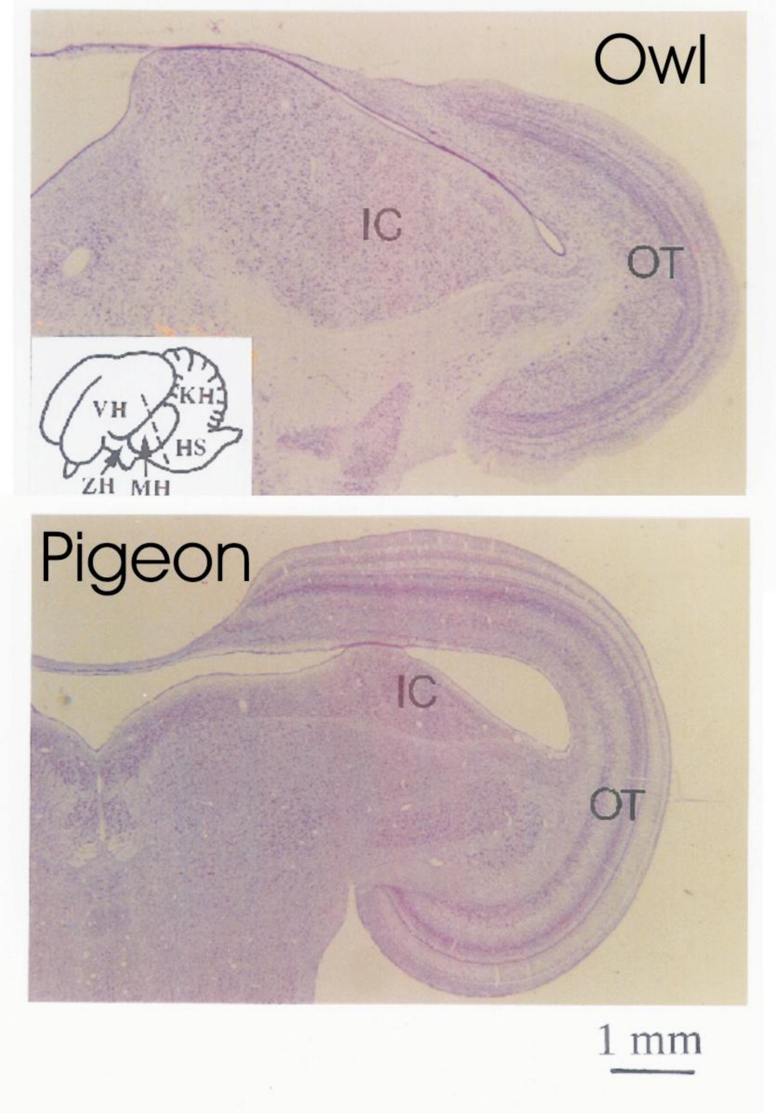
Barn owls as model system for sound localization

- Facial ruff serves as a sound amplifier
- Asymmetric ears allow for an increased spatial resolution in the vertical plane
- Comb-like structures at the leading edge of the wing reduce noise during flight

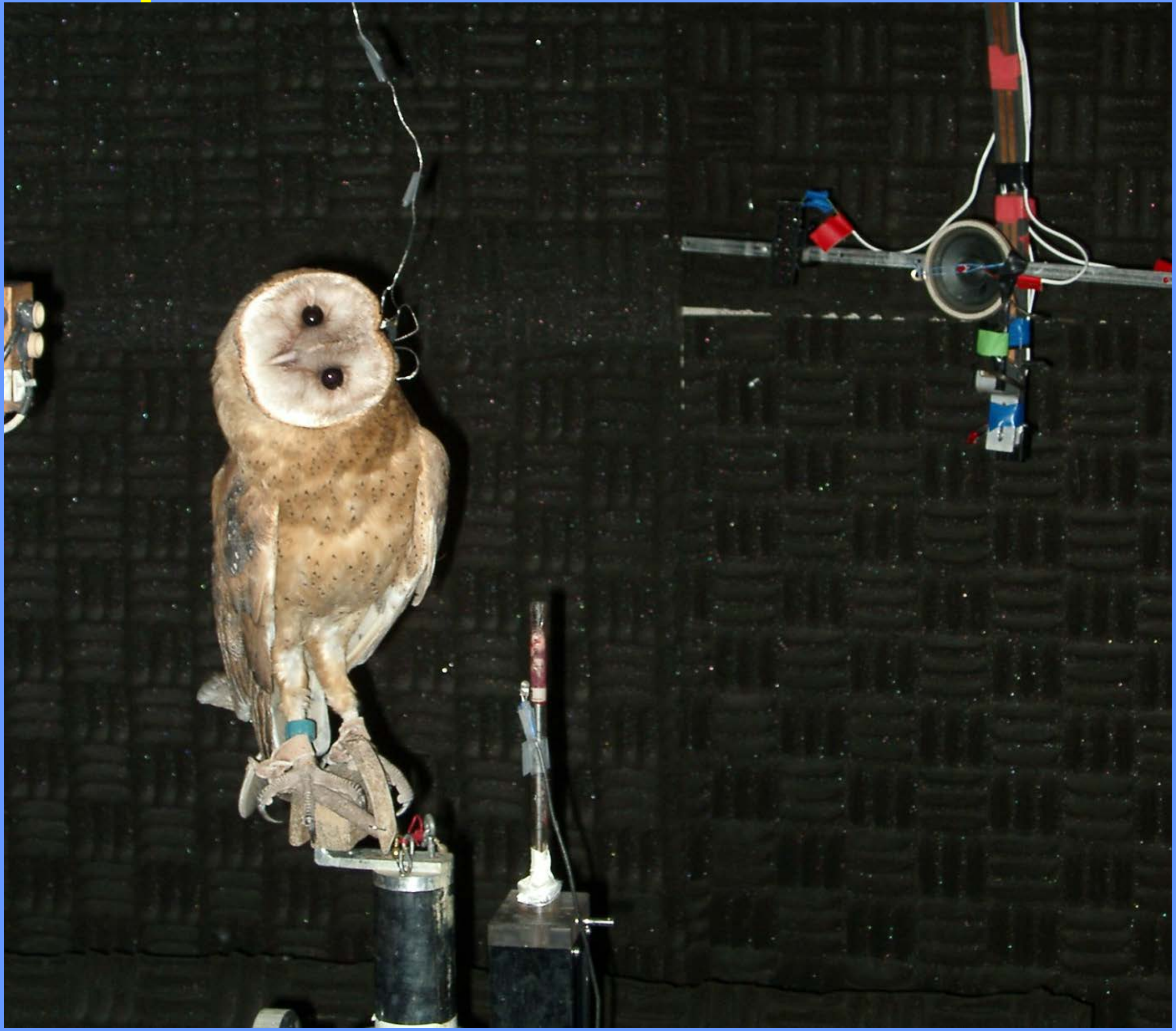


Barn owls as model system for sound localization

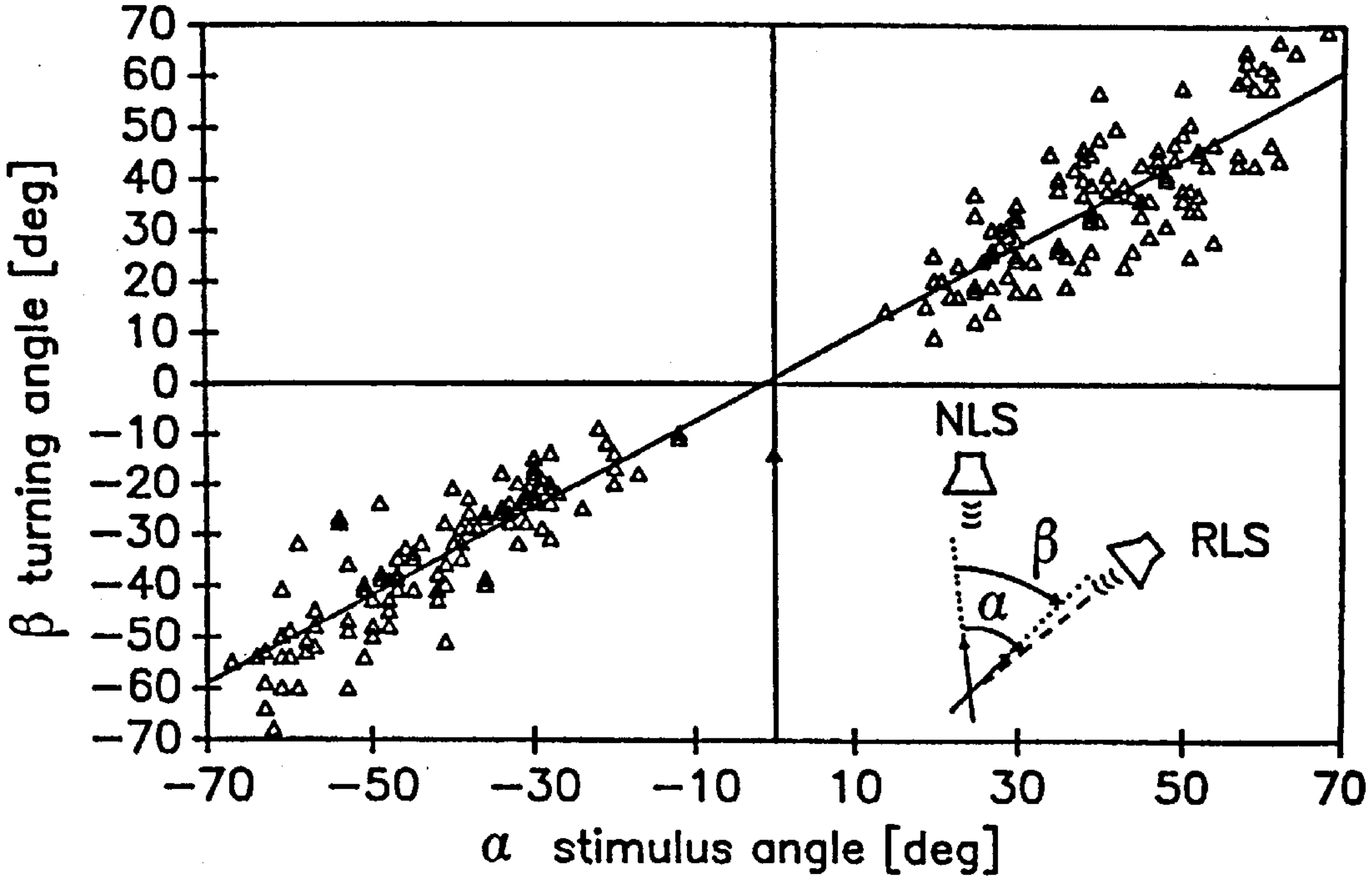
- Facial ruff serves as a sound amplifier
- Asymmetric ears allow for an increased spatial resolution in the vertical plane
- Comb-like structures at the leading edge of the wing reduce noise during flight
- Brain structures involved in the analysis of sound are enlarged



Performing a psychoacoustic experiment with an owl



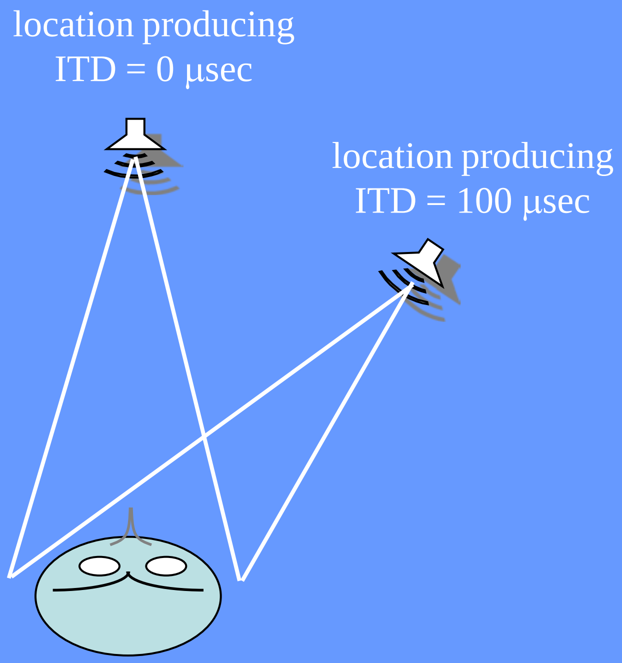
Sound-localization with free-field stimuli

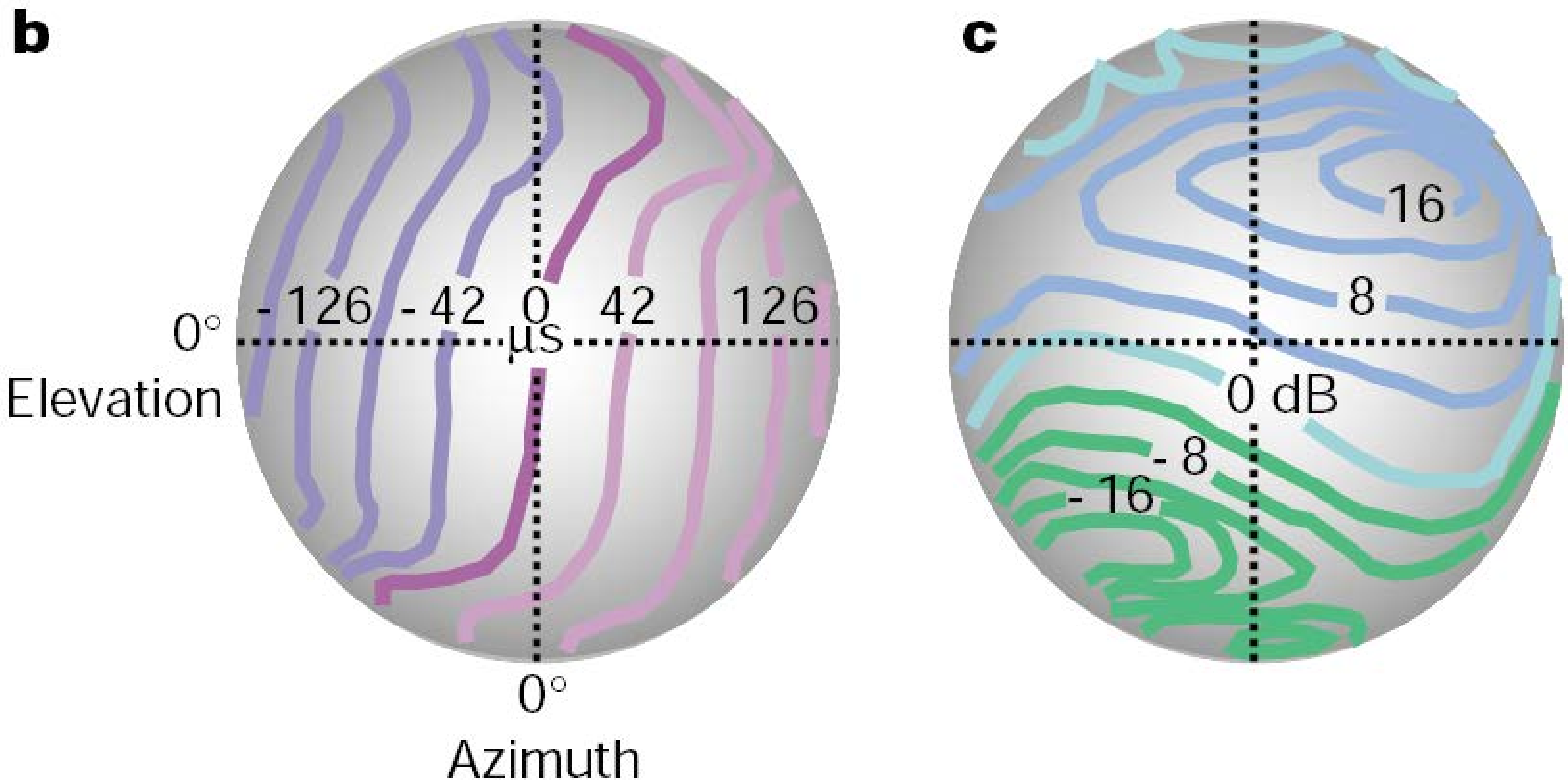


- The auditory localization cues:

- ITD - horizontal

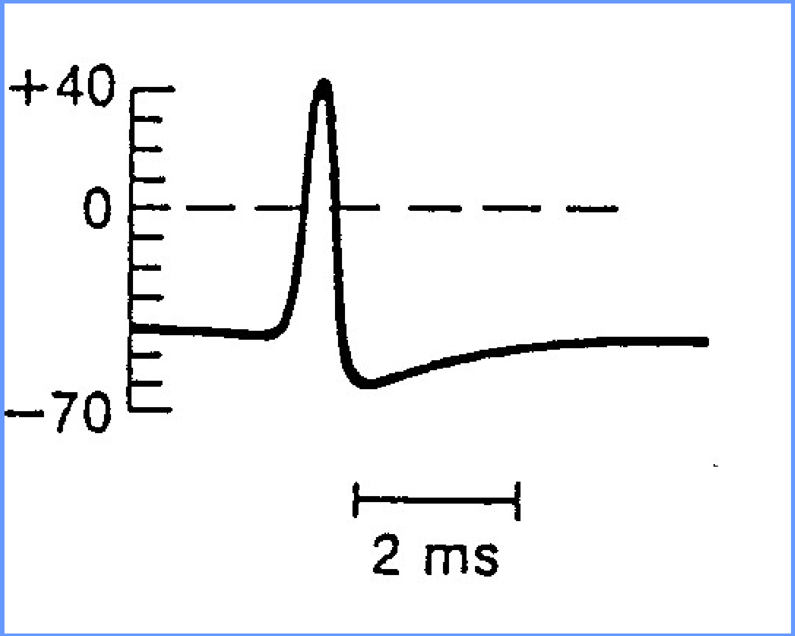
ILD - vertical



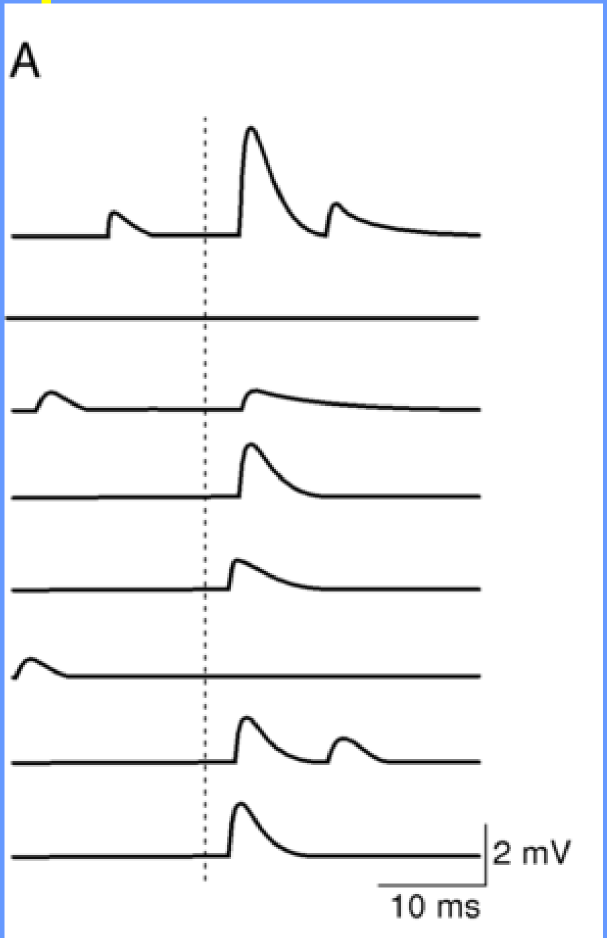

b
c
- 126
- 42
0
42
126
µs
0°
Elevation
0°
Azimuth
16
8
0 dB
- 8
- 16

Precision of sound localization in barn owls may be as good as 3 deg which corresponds to 6-10 μs.

Action potential



Postsynaptic potentials



These signals are the “language" of neural processing.

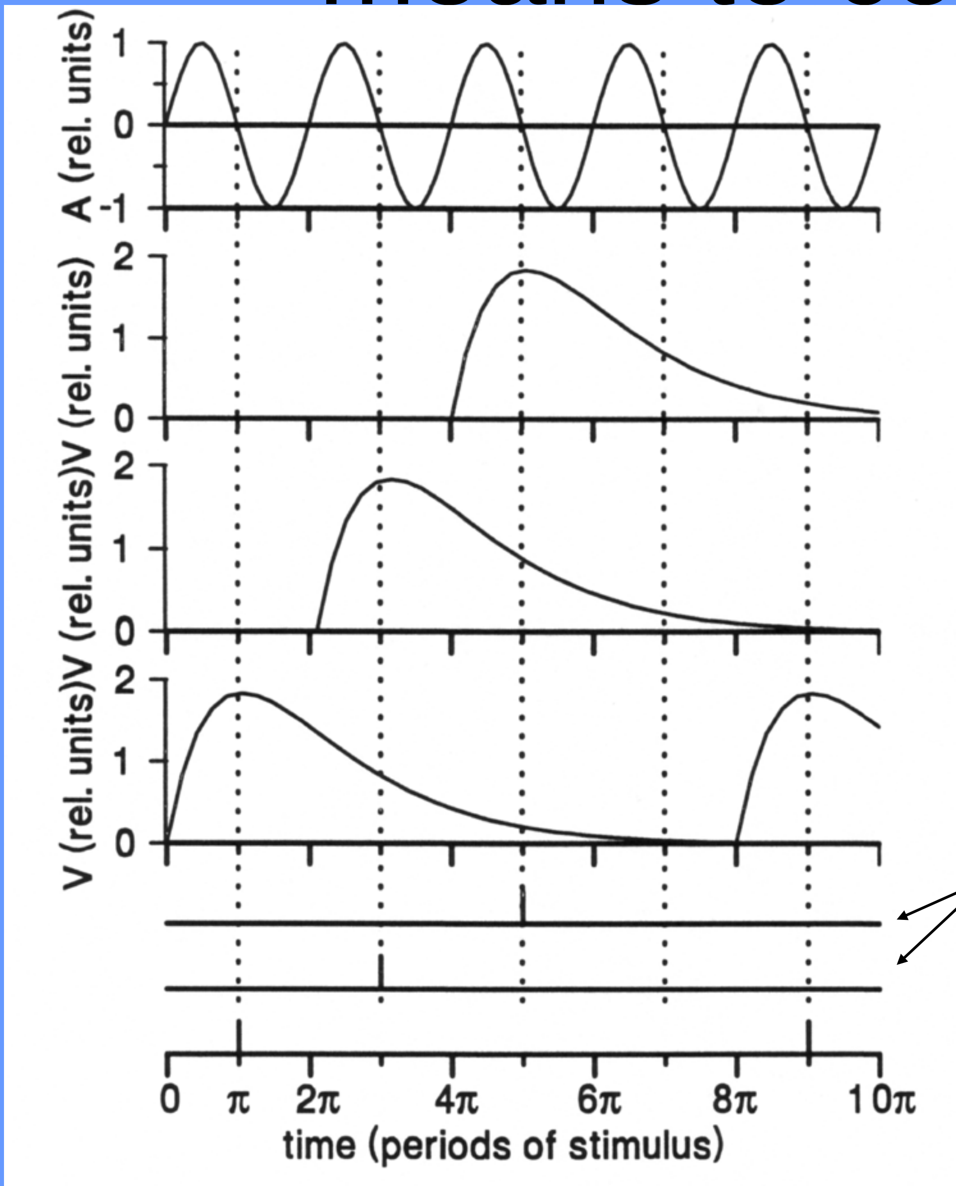
Durations of events

- Typical duration of action potential: 1ms
- Typical duration of post-synaptic potentials: 5-10 ms
- Precision of sound localization by interaural time difference: 6-10 μs

What has to be explained is

Factor of 500-1000

The principle of phase locking as a means to conserve time



Sinusoidal signal

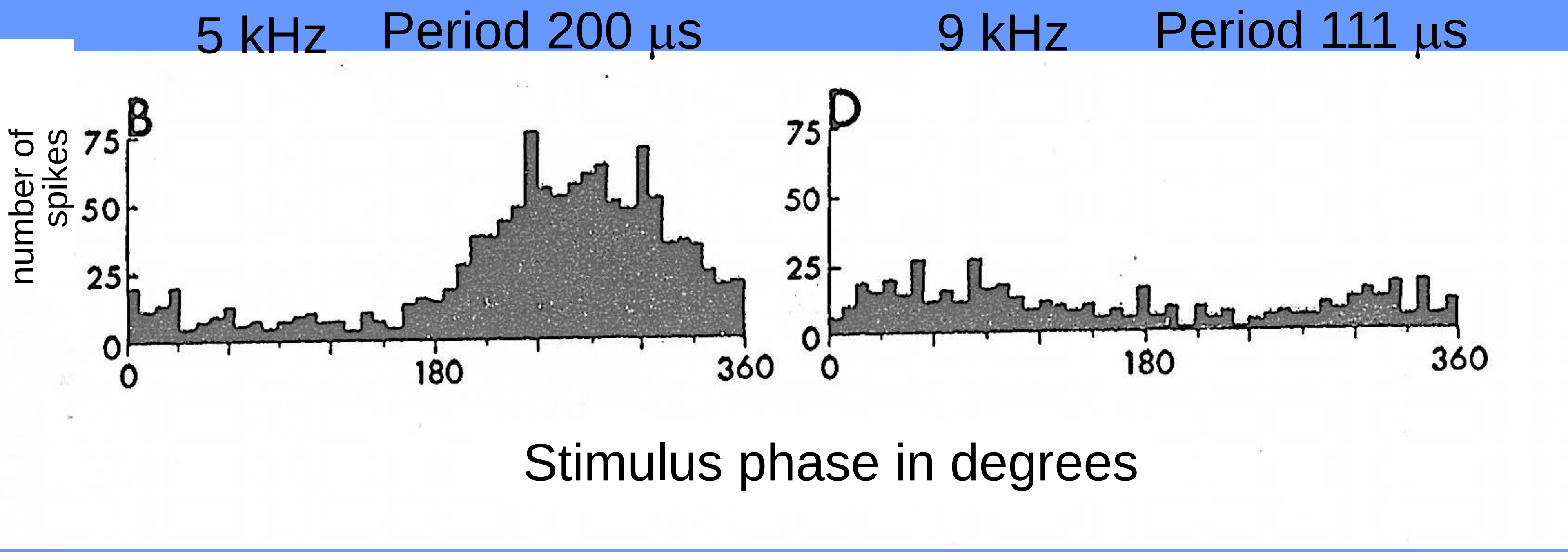
Presumed resulting post-synaptic potential

Registered signal in computer

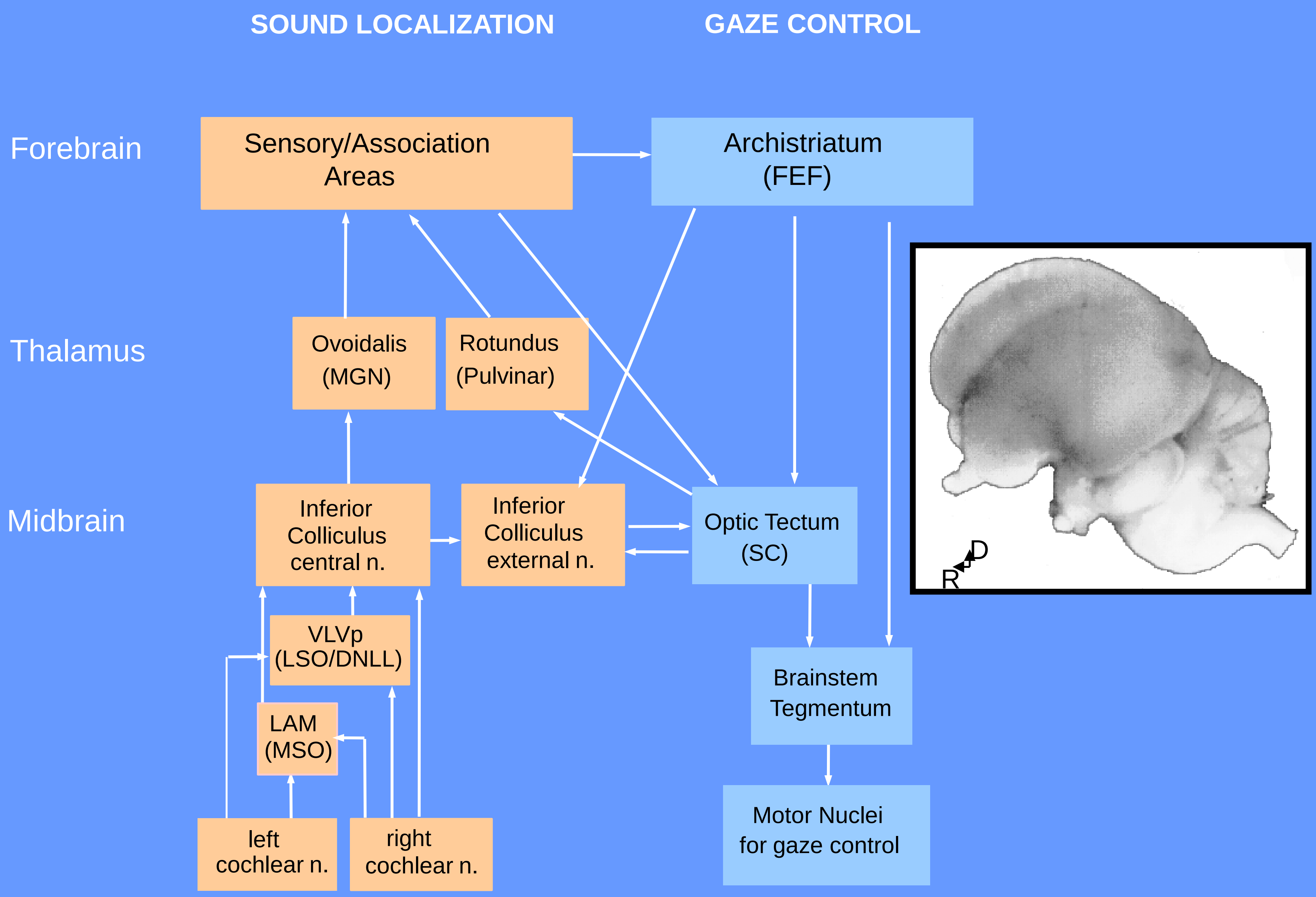
Note that in this example the response always occurs at a phase of 180 degrees.

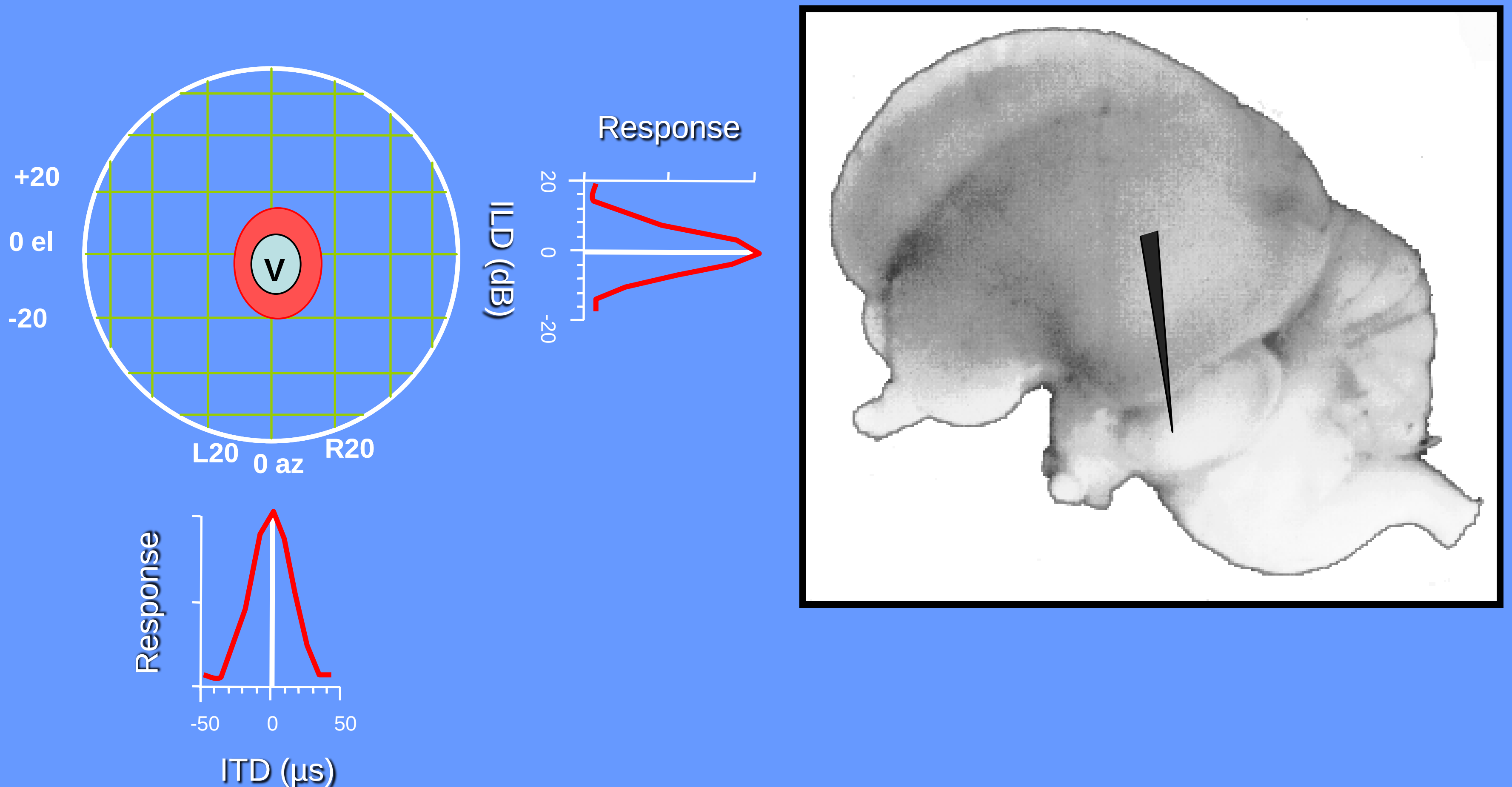
Phase locking in the barn owl

Phase locking can be measured by plotting spike arrival times with respect to the period of the stimulus tone.

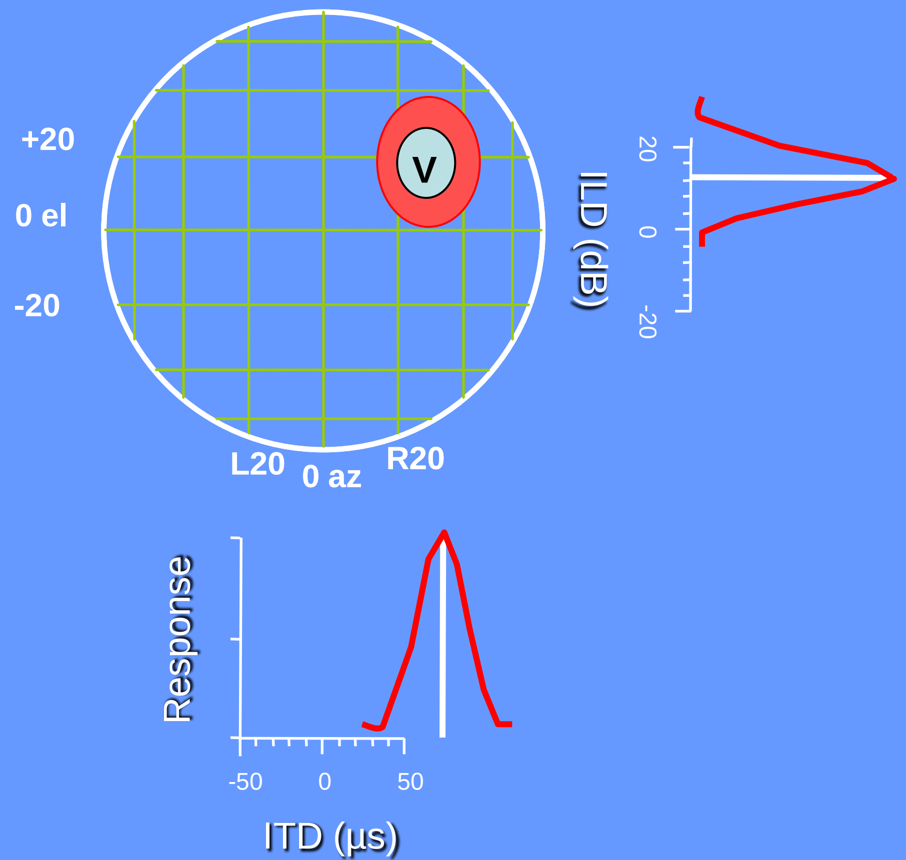


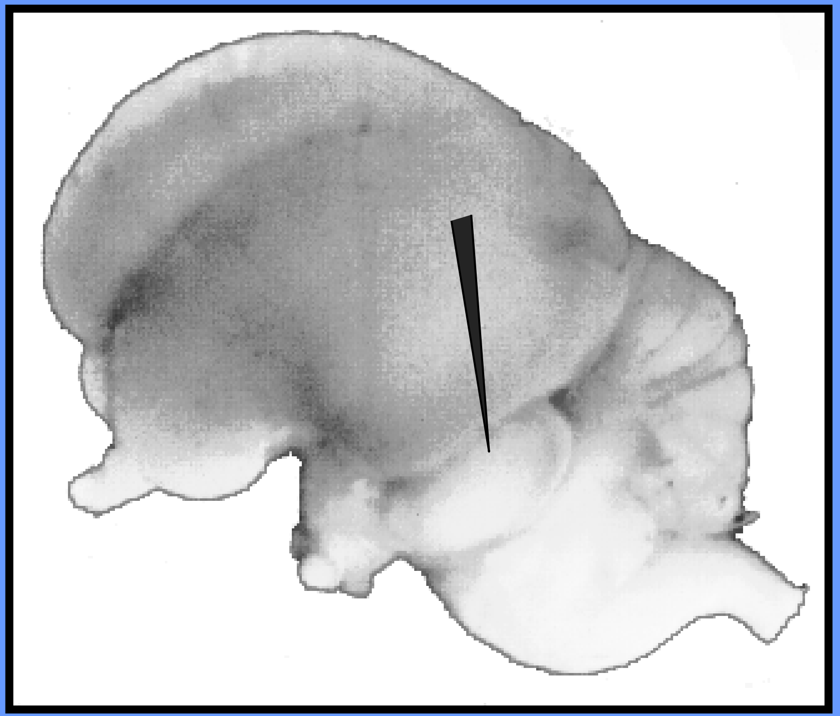
Precision of phase locking is 35 μs at 5 kHz (Koeppl (1997)).


SOUND LOCALIZATION
GAZE CONTROL
Forebrain
Thalamus
Midbrain
Sensory/Association Areas
Archistriatum (FEF)
Ovoidalis (MGN)
Rotundus (Pulvinar)
Inferior Colliculus central n.
Inferior Colliculus external n.
Optic Tectum (SC)
VLVp (LSO/DNLL)
LAM (MSO)
left cochlear n.
right cochlear n.
Brainstem Tegmentum
Motor Nuclei for gaze control
D
R

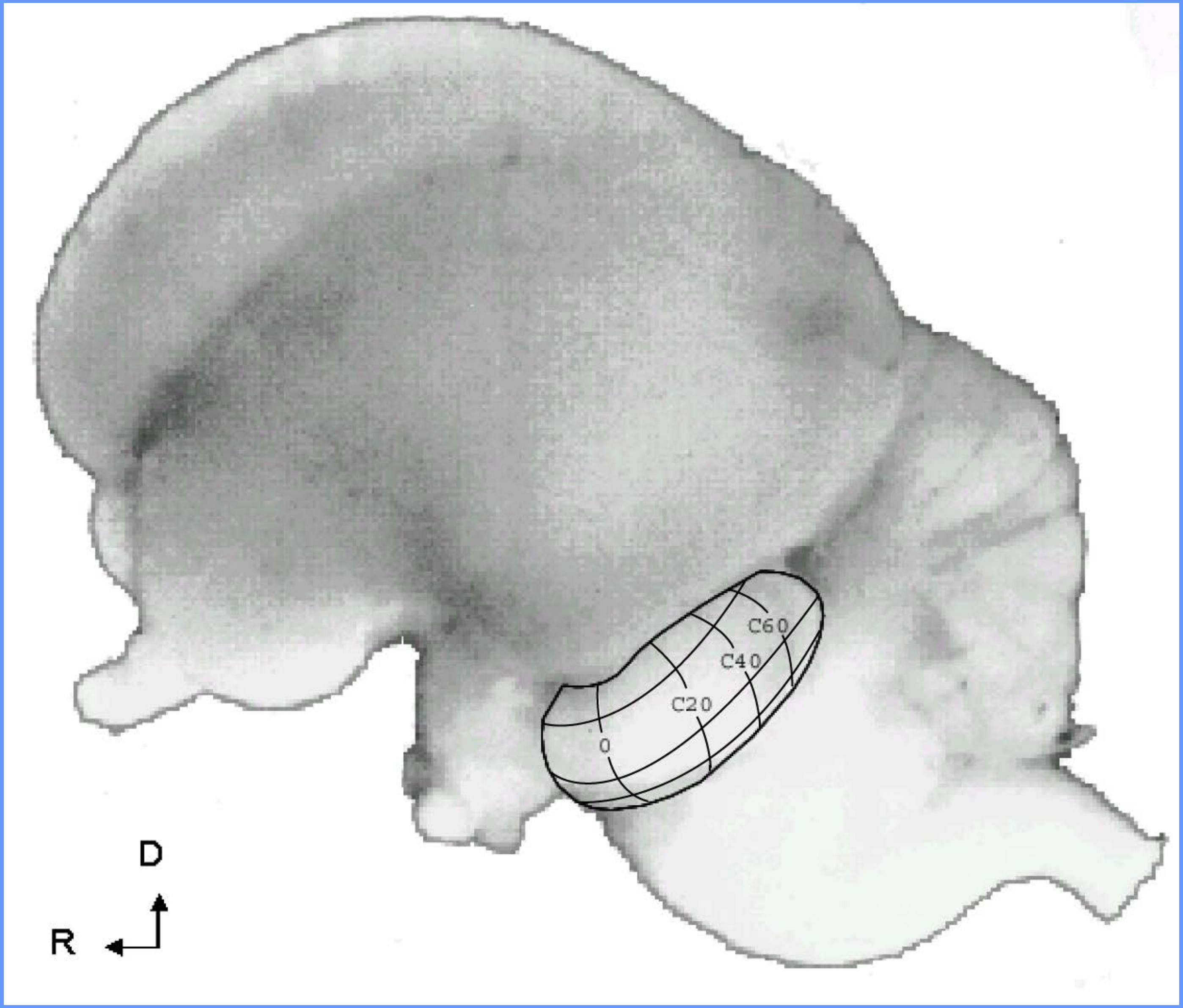


+20
0 el
-20
V
L20
0 az
R20
Response
20
0
-20
ILD (dB)
Response
-50
0
50
ITD (µs)

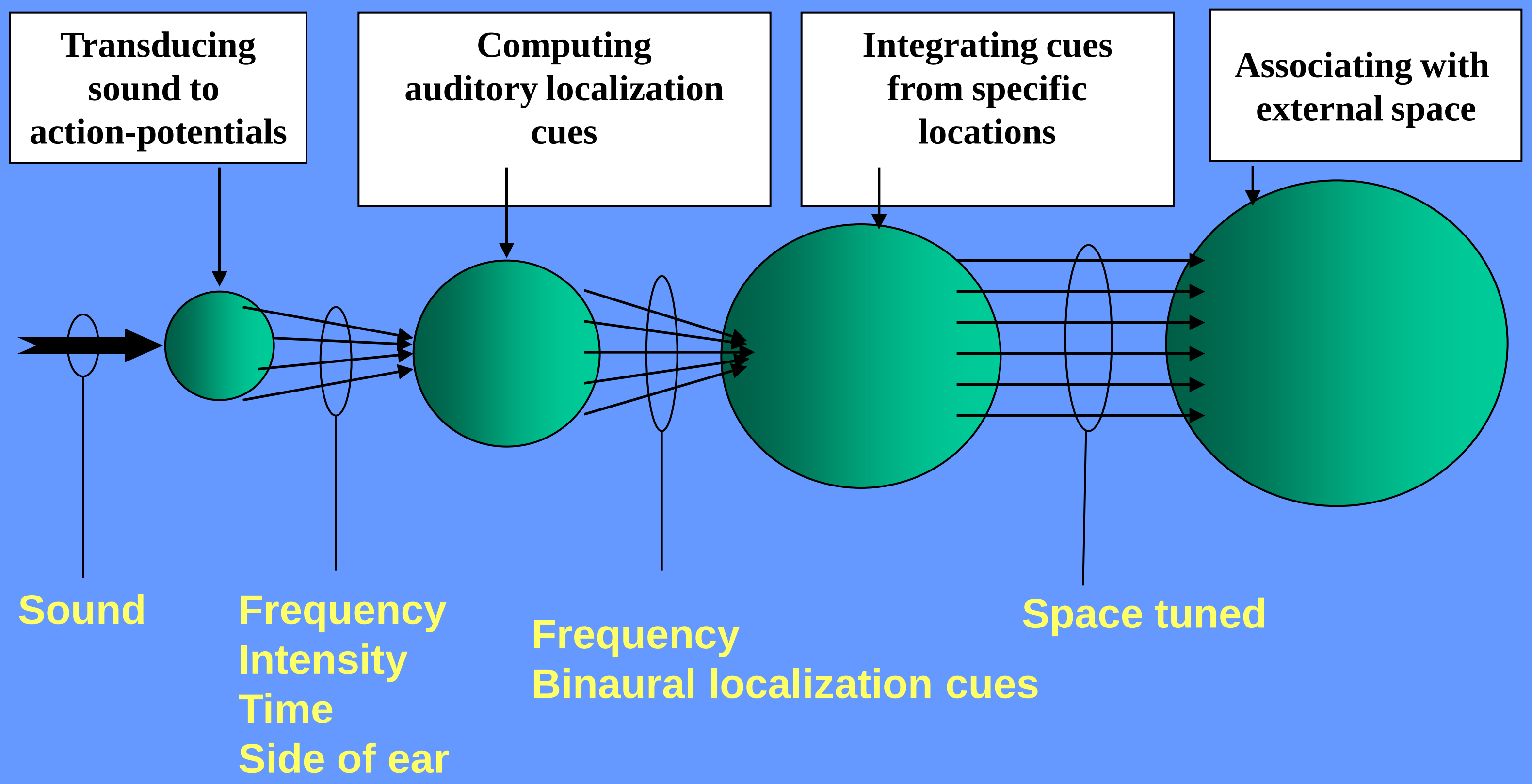

+20
0 el
-20
V
L20
0 az
R20
ILD (dB)
20
0
-20
Response
-50
0
50
ITD (µs)



Visual and auditory maps in the OT

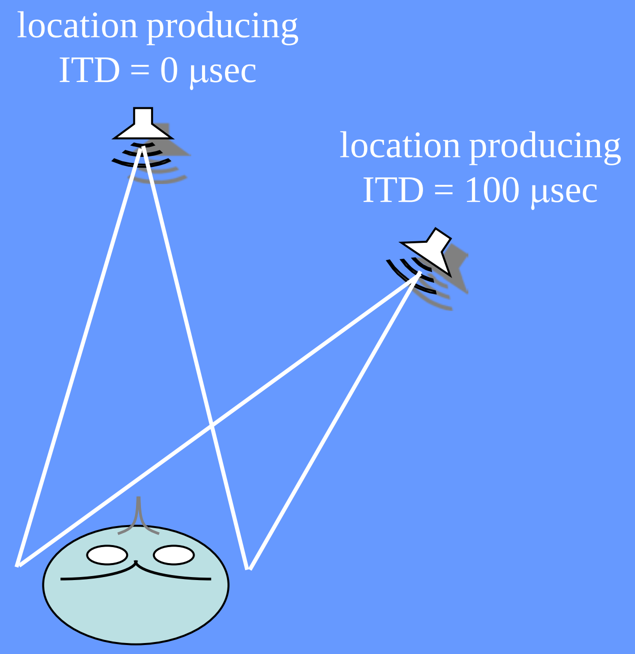


Computational map



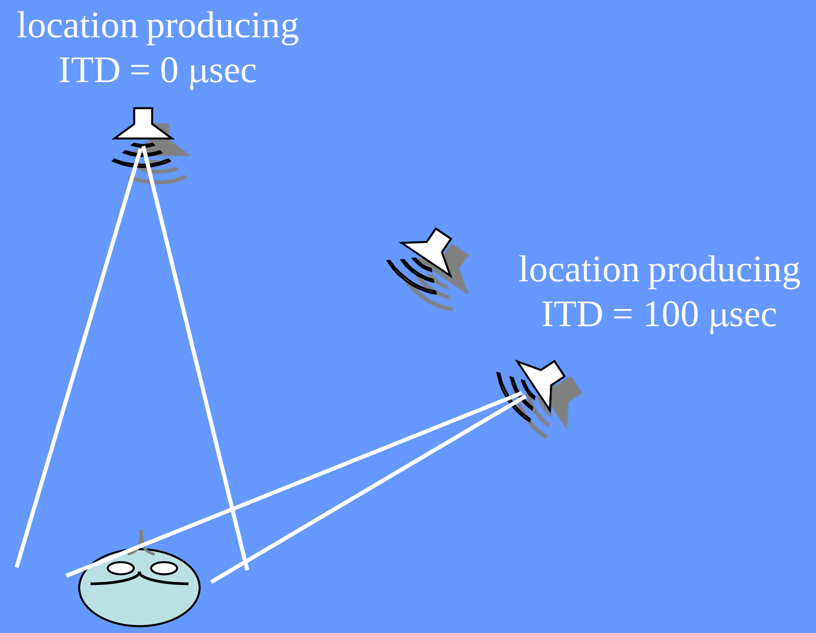
Computational maps

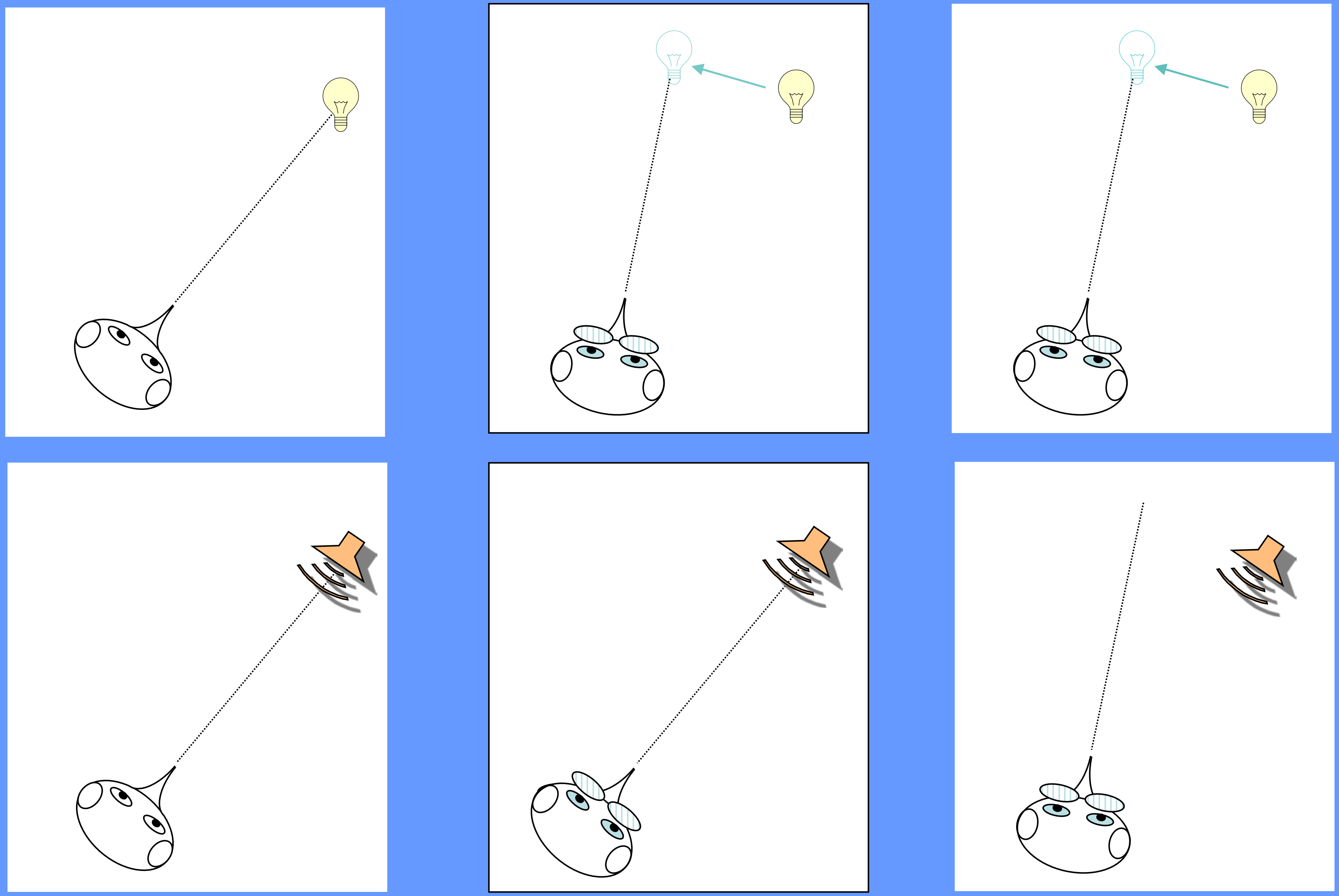
The matching problem



Computational maps

The matching problem

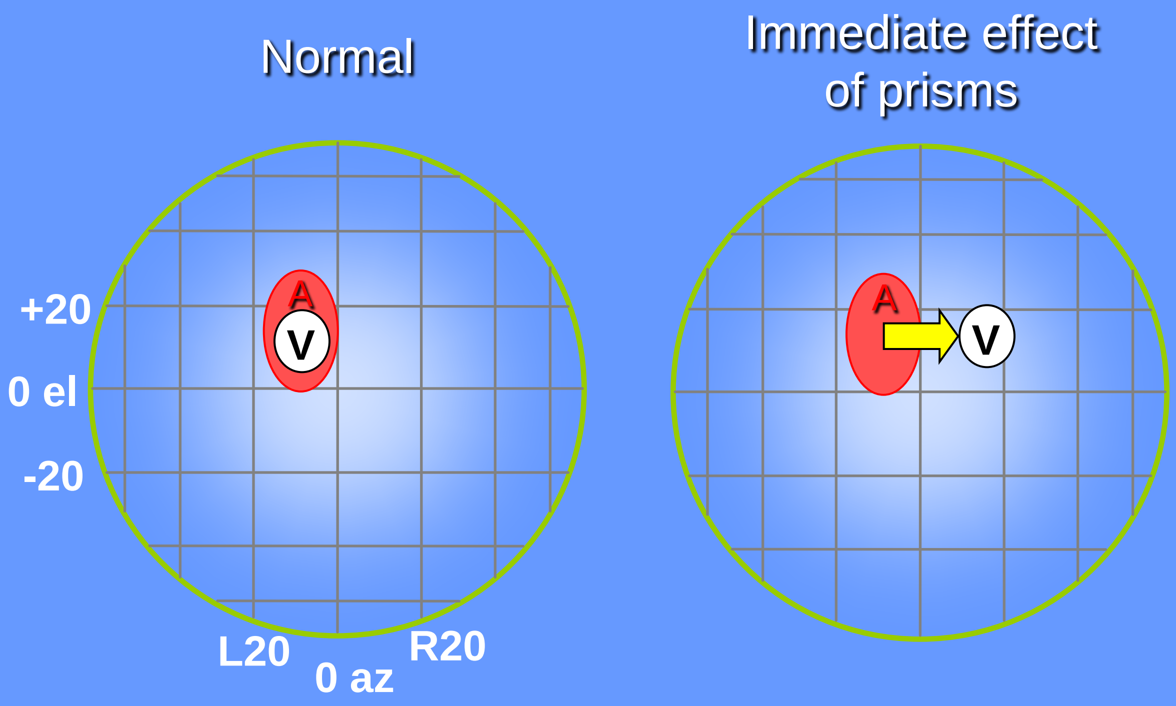




Normal | **Immediate Effect of Prisms** | **Prism-adapted**

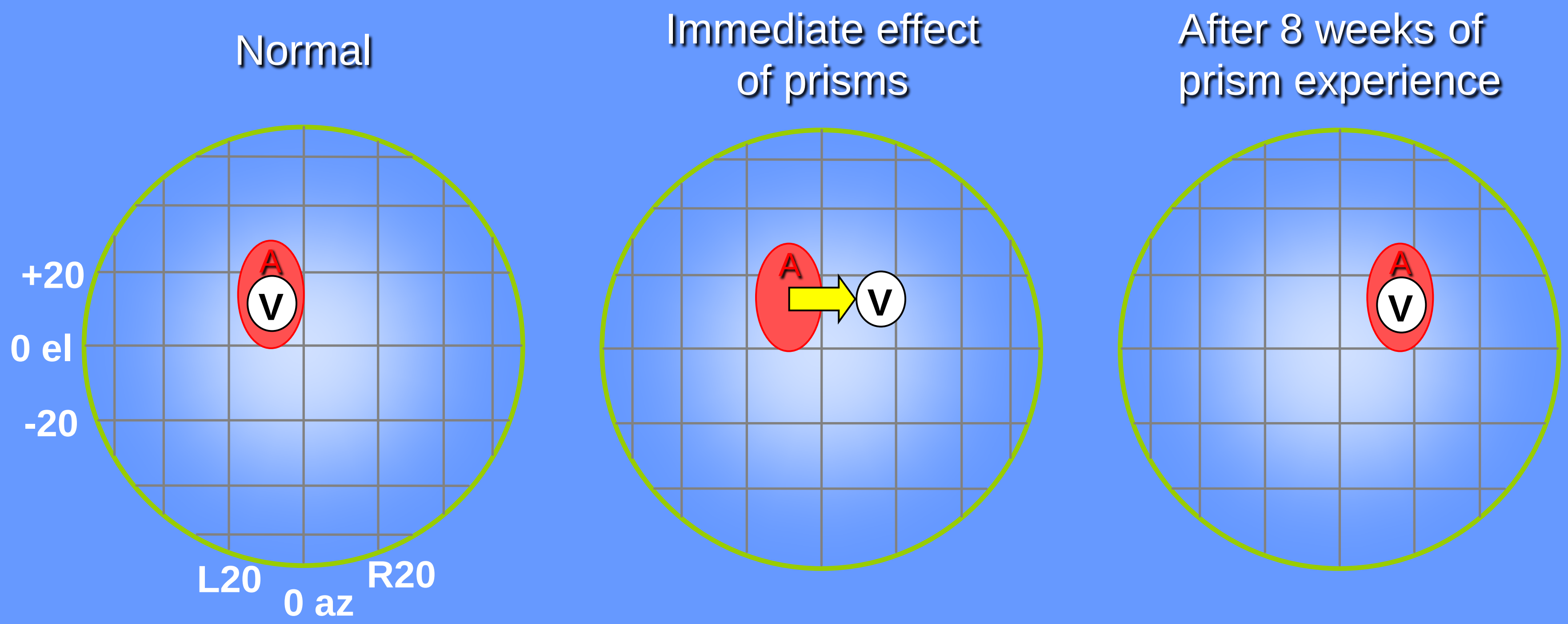
Knudsen and Knudsen J Neurosci (1989)

Effect of prism experience on auditory tuning



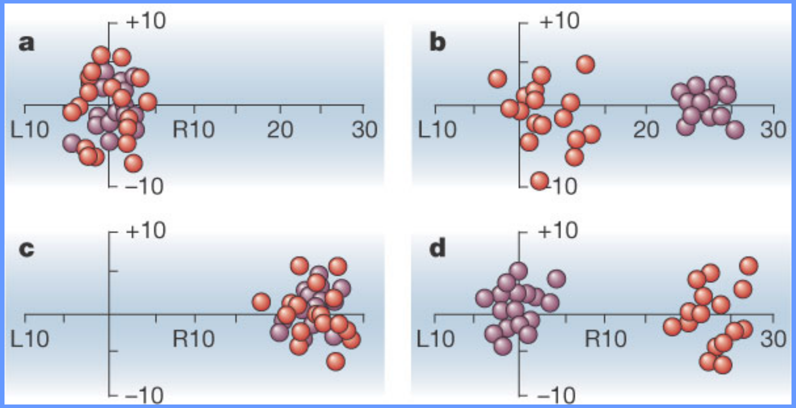
Knudsen and Brainard, Science (1991)

Effect of prism experience on auditory tuning

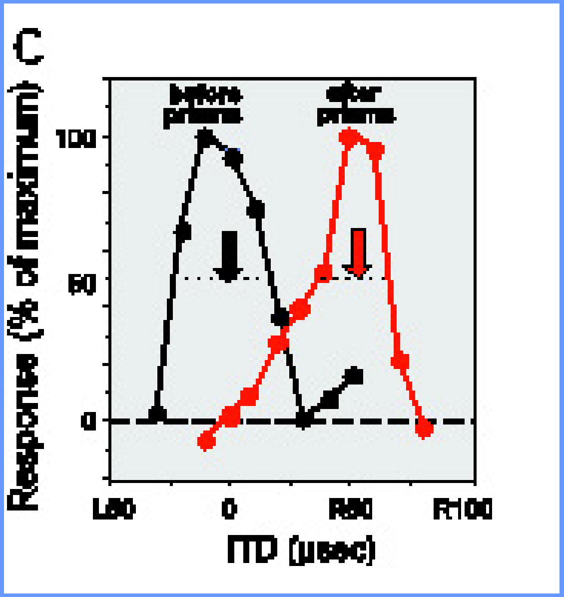


Quantification of learning

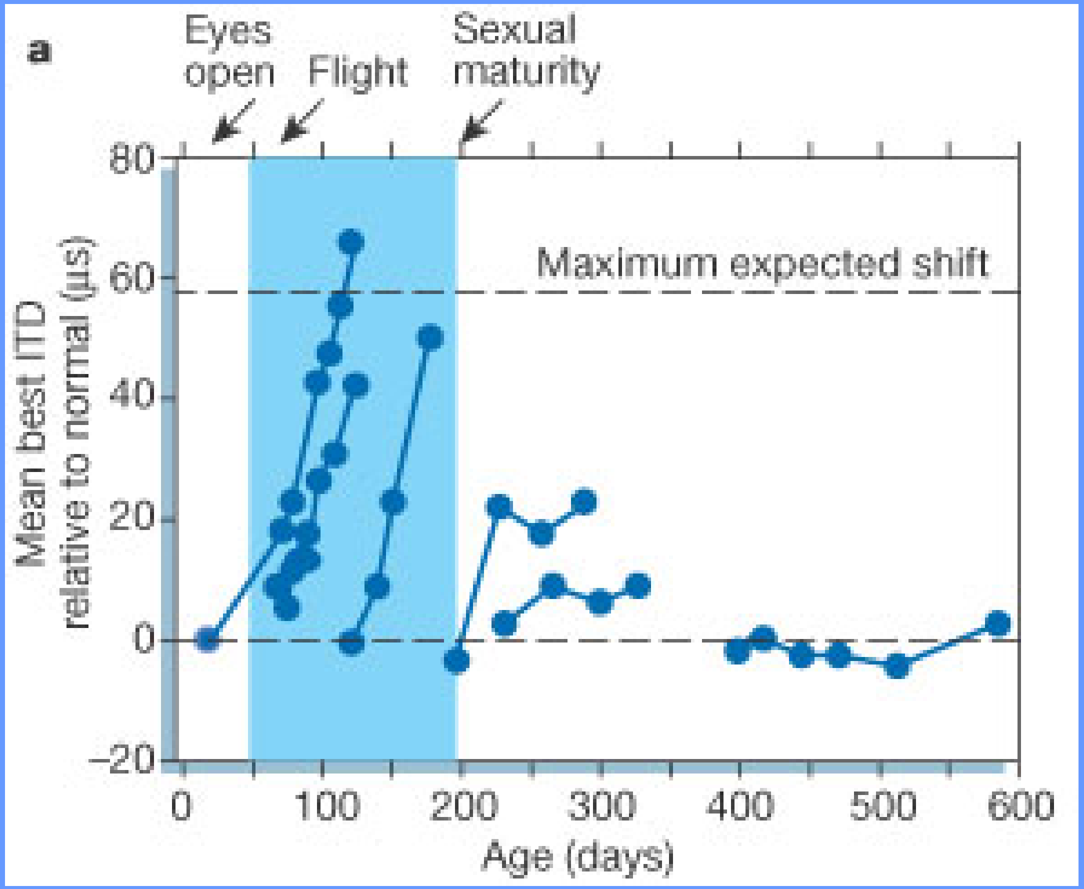
1. Behavioral test



2. Physiological test

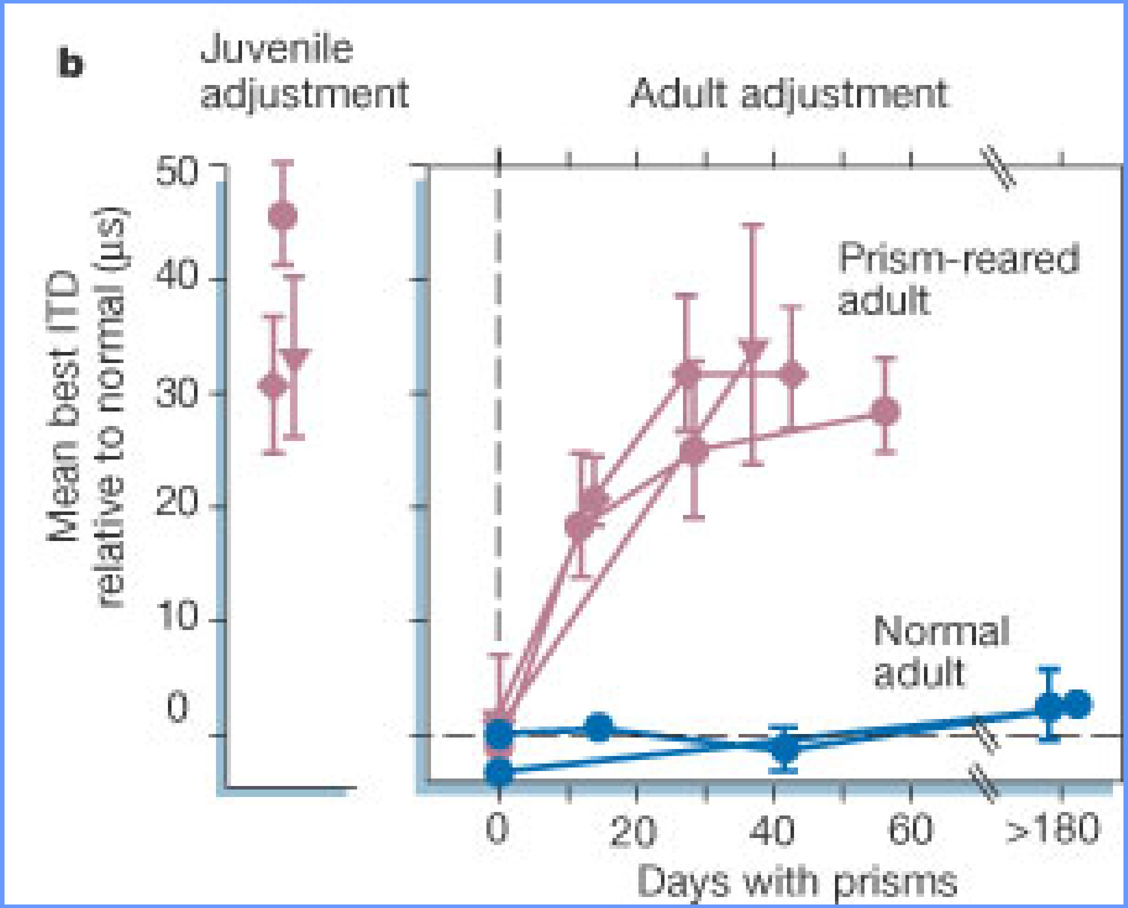


Decline in learning with age



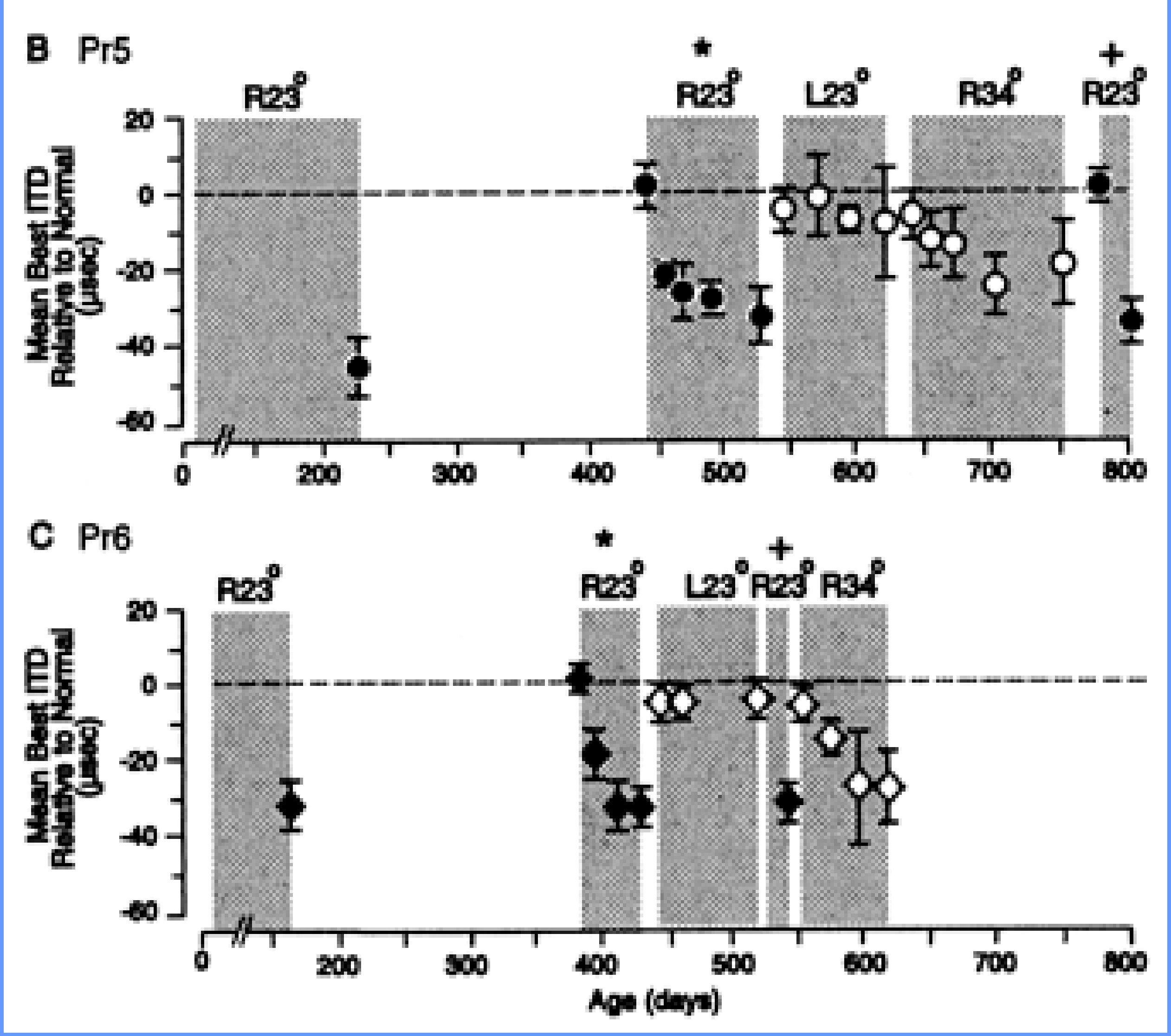
67. Knudsen, E. I. *Science*.(1998)

Increased capacity for learning in adults that have had appropriate experience as juveniles



Knudsen, E. I. *Science*.(1998)

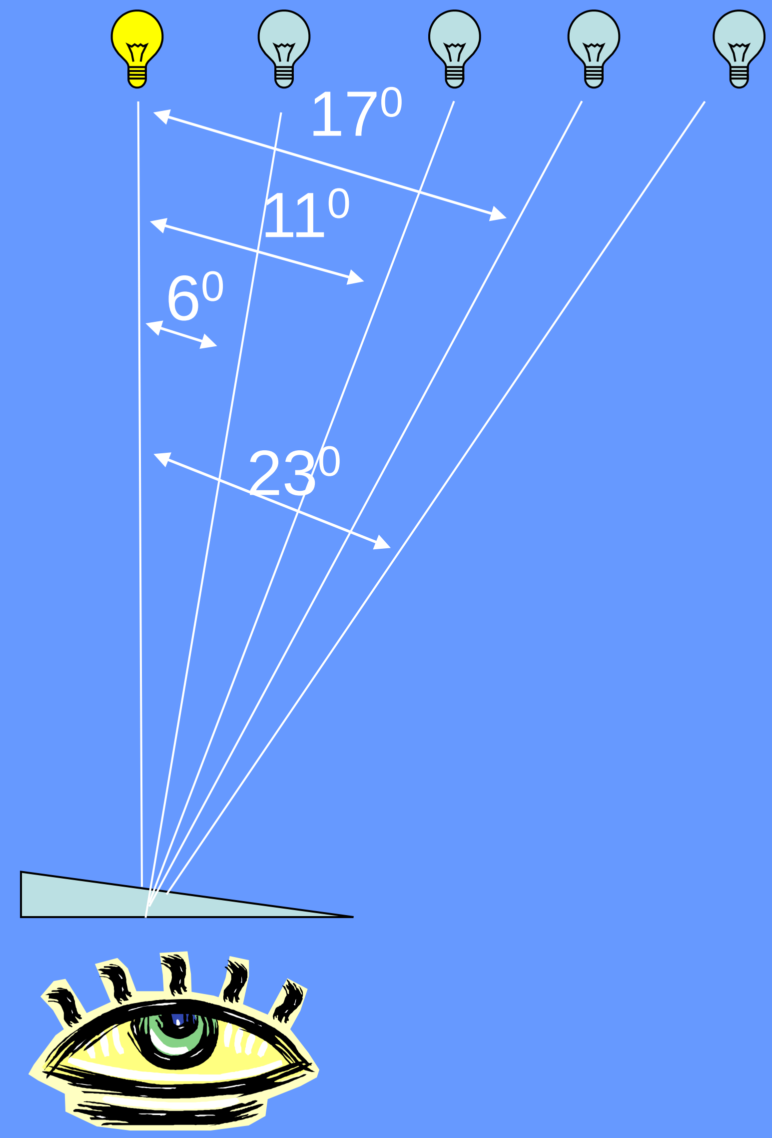
Effects of juvenile experience on adult learning



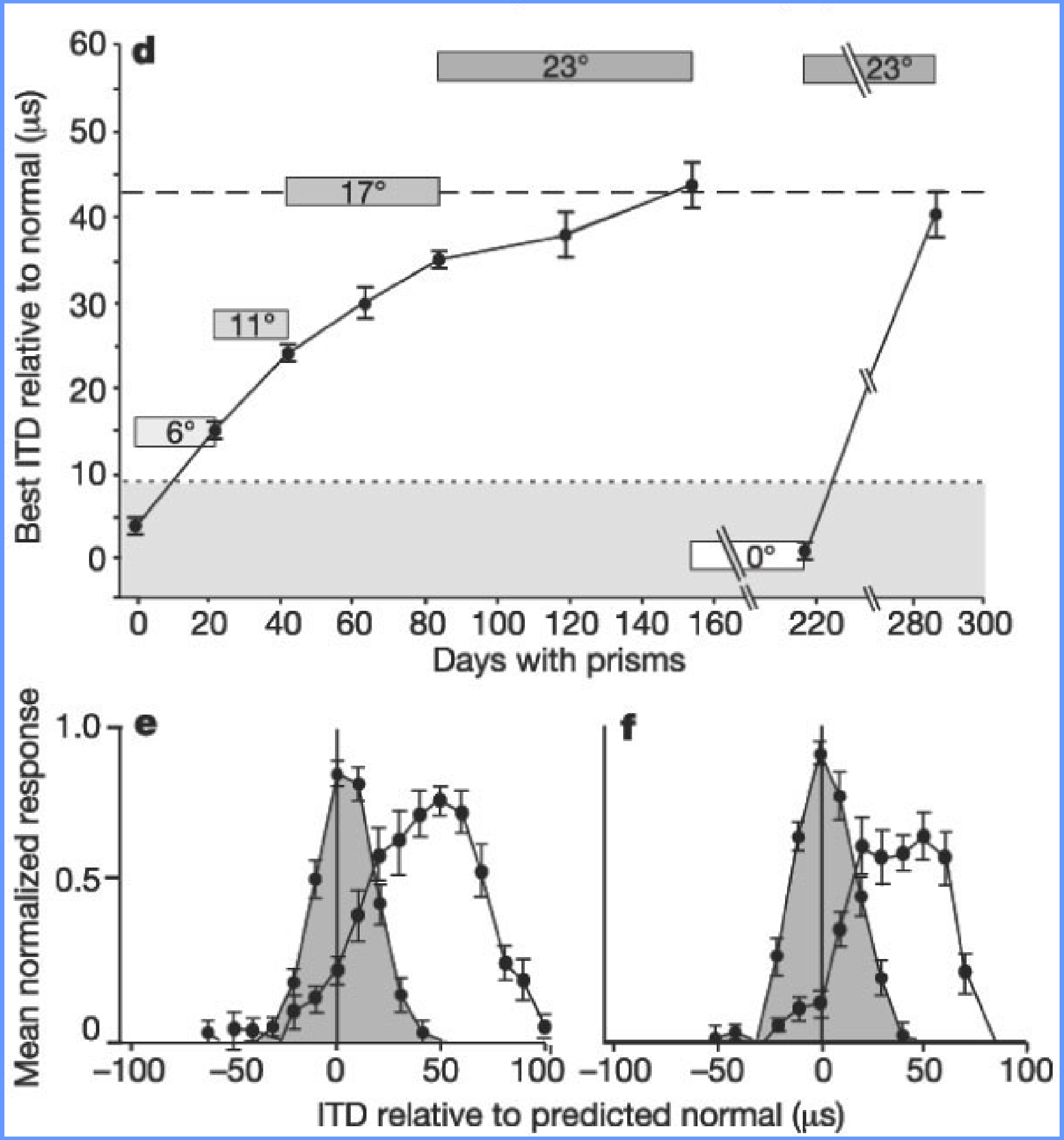
67.

Knudsen, E. I. *Science*.(1998)

Incremental learning

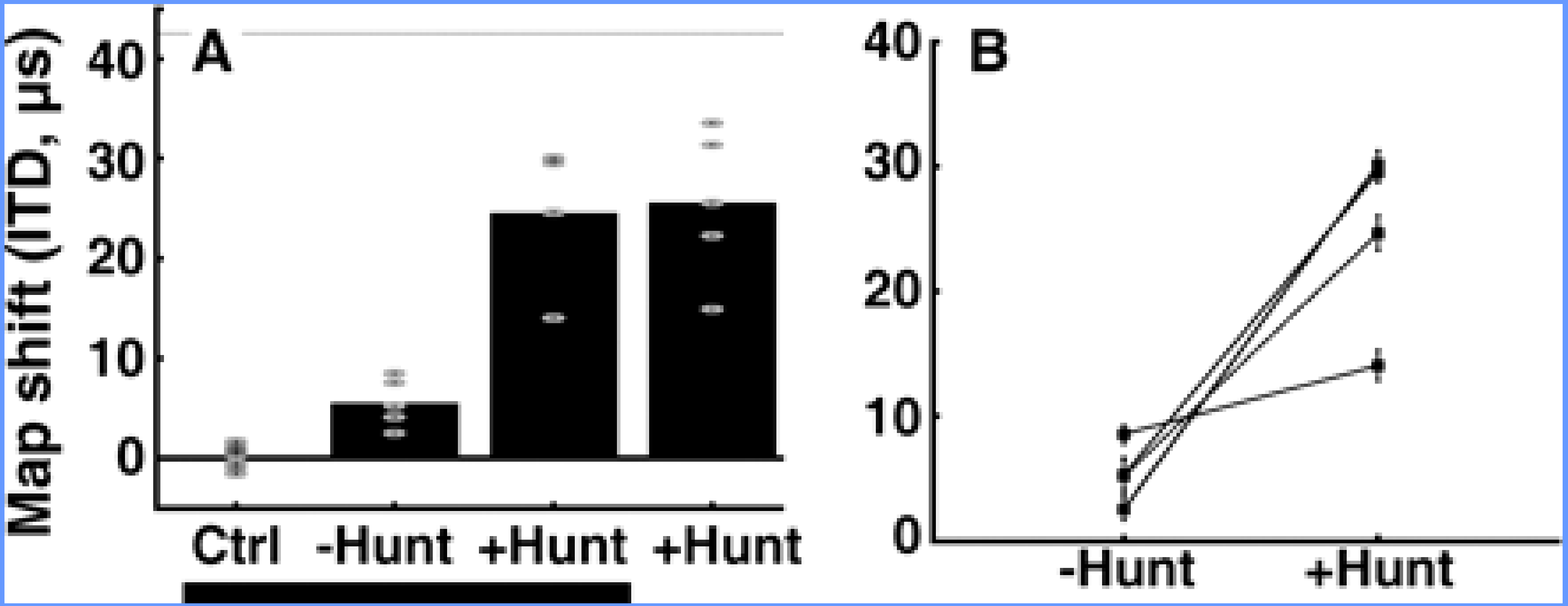


Incremental learning



Linkenhoker and Knudsen (2002) Nature

Rich and lively experiences increase learning capacity in adults

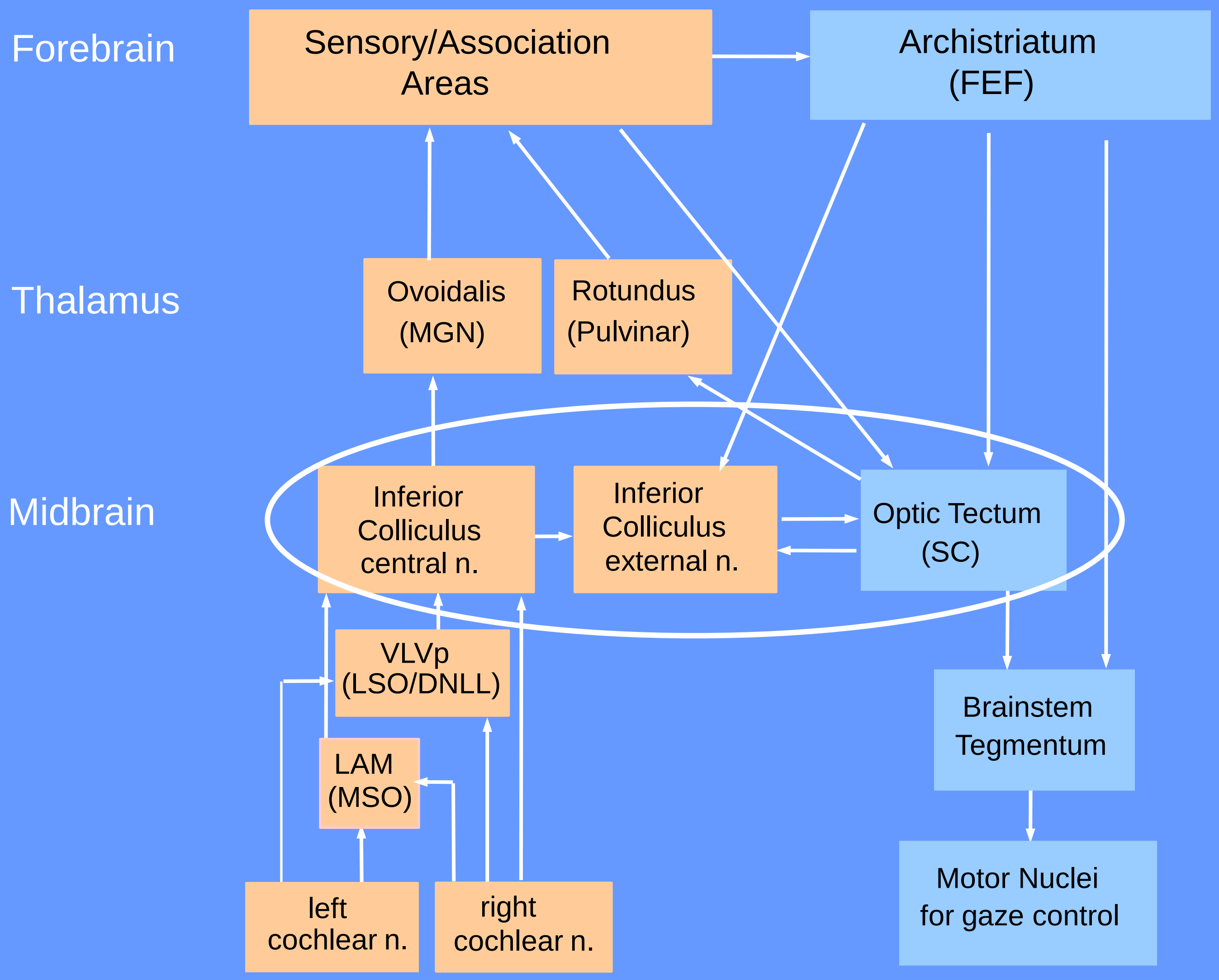


Bergan et al., Journal of Neuroscience (2005)

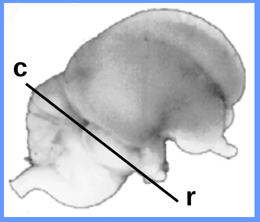
Summary

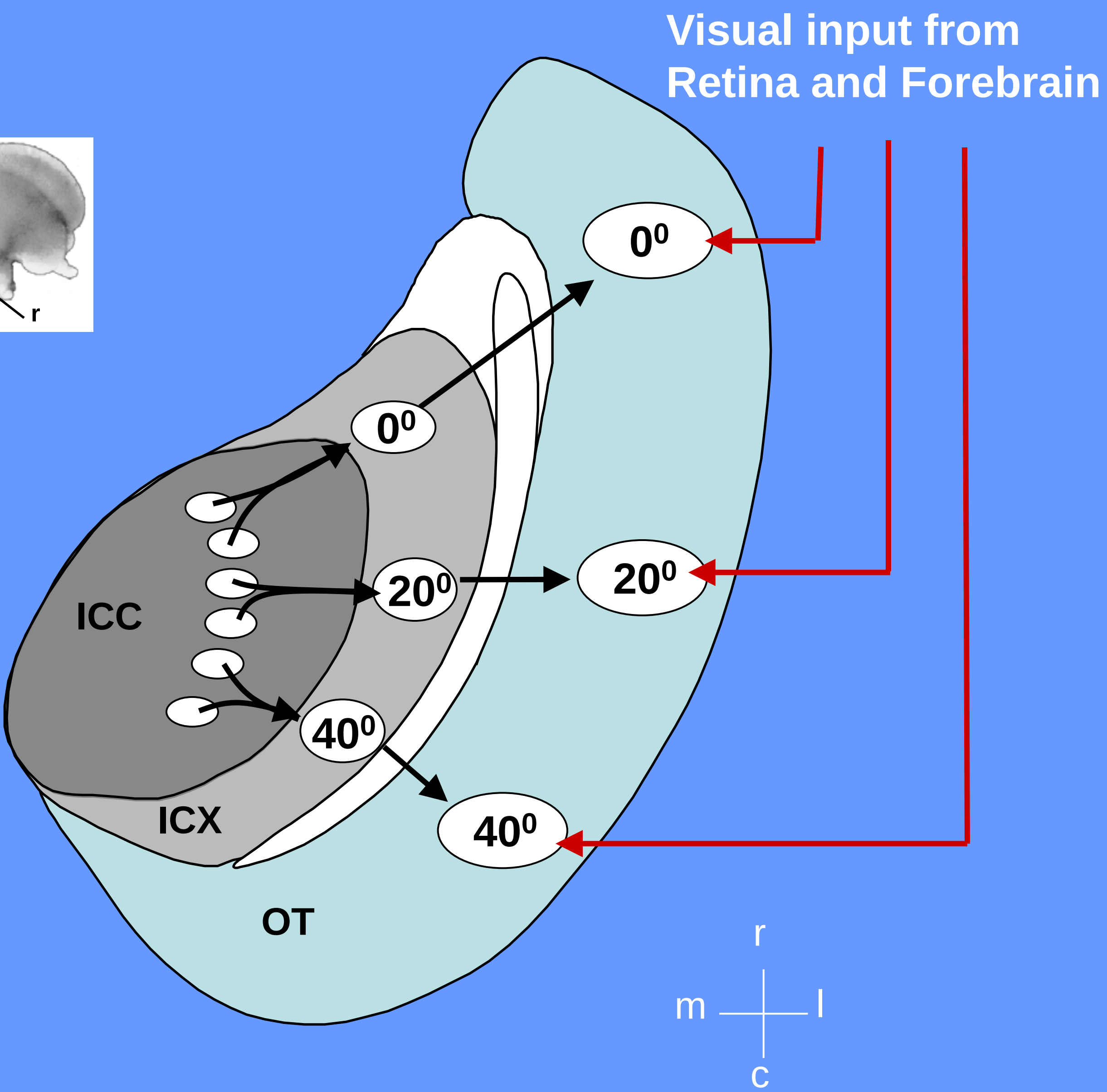
- Decline in learning with age
- Increased capacity for learning in adults that have had appropriate experience as juveniles
- Incremental training improves learning
- Rich and lively experiences increase learning capacity in adults

Where is the site of plasticity?

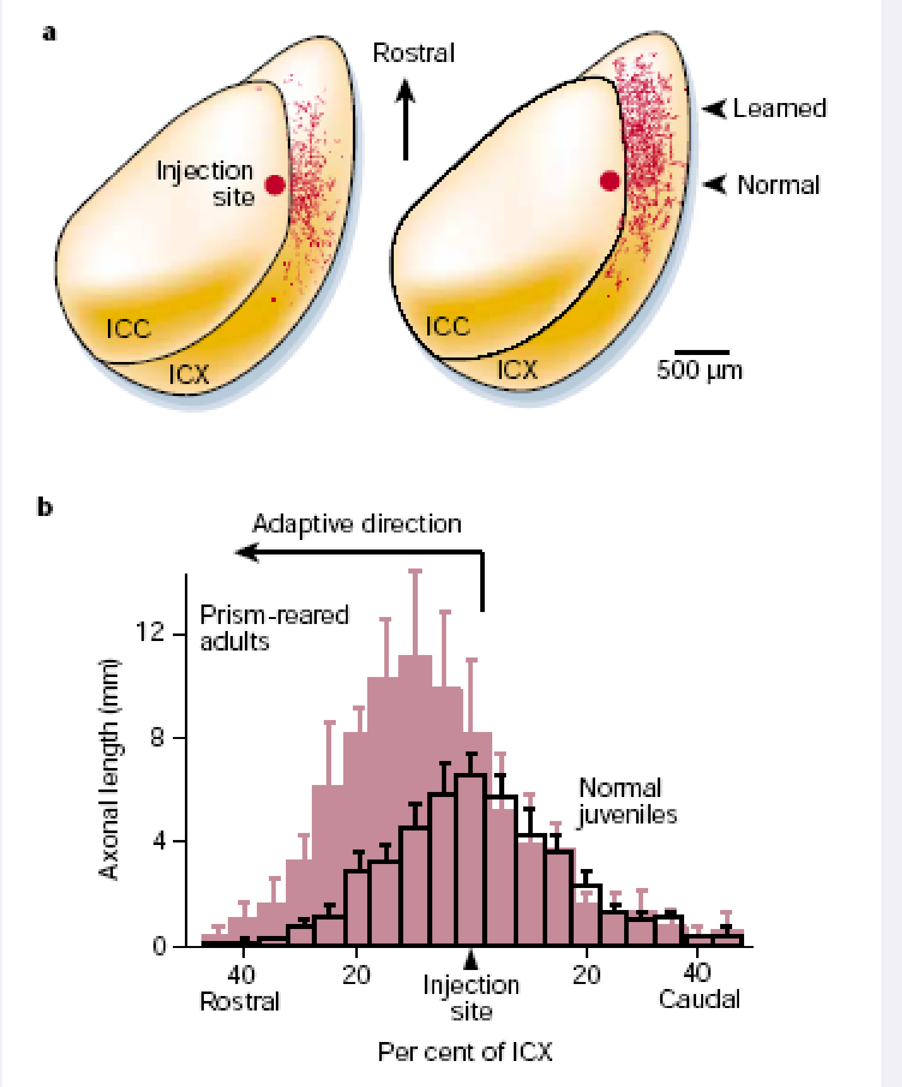


Horizontal section through the tectal lobe



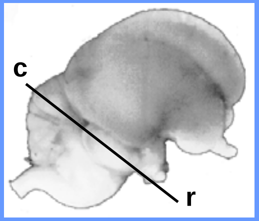


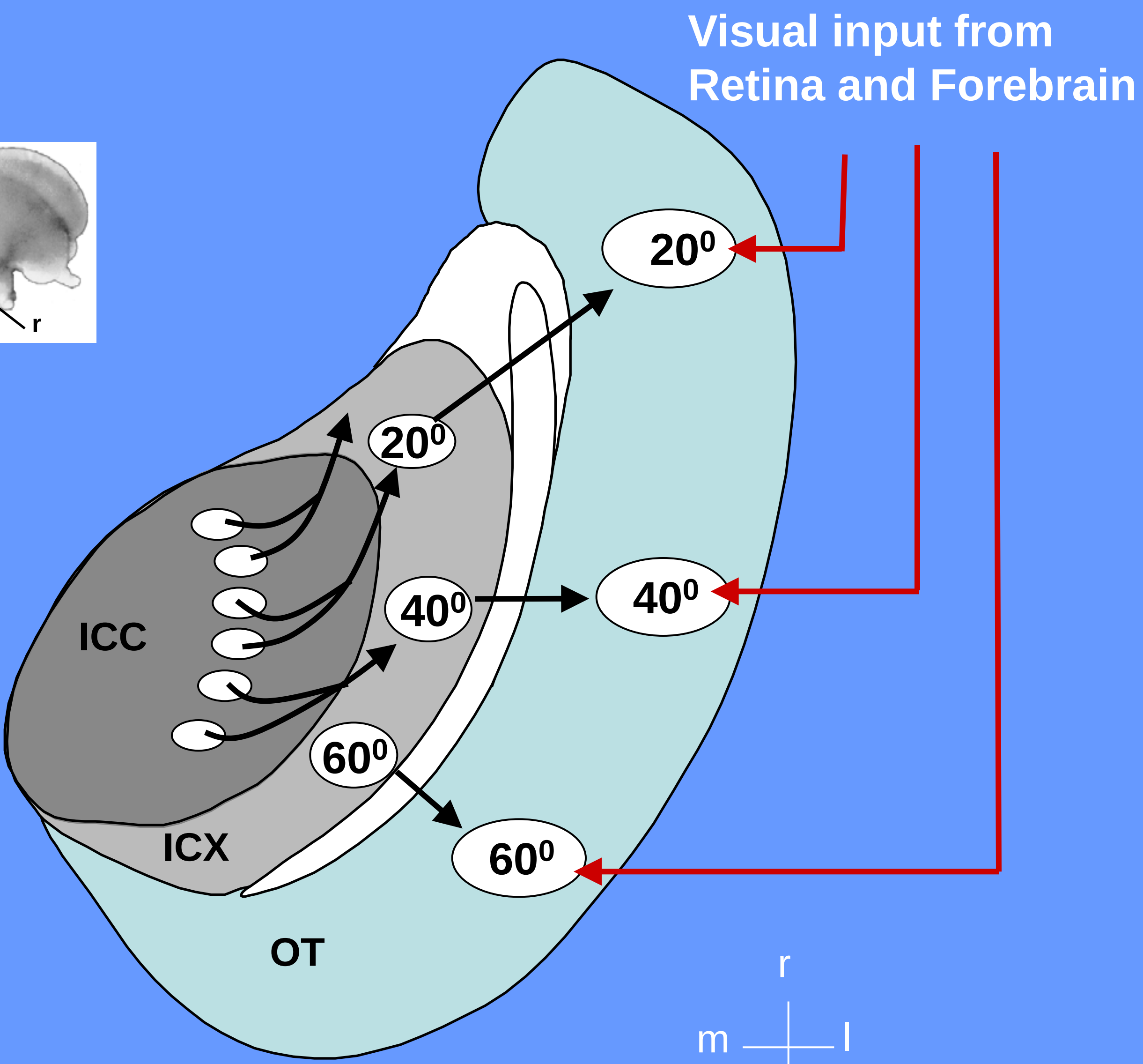
Site of plasticity in the ICX



Debello et al., J. Neurosci. 2001

After prism learning





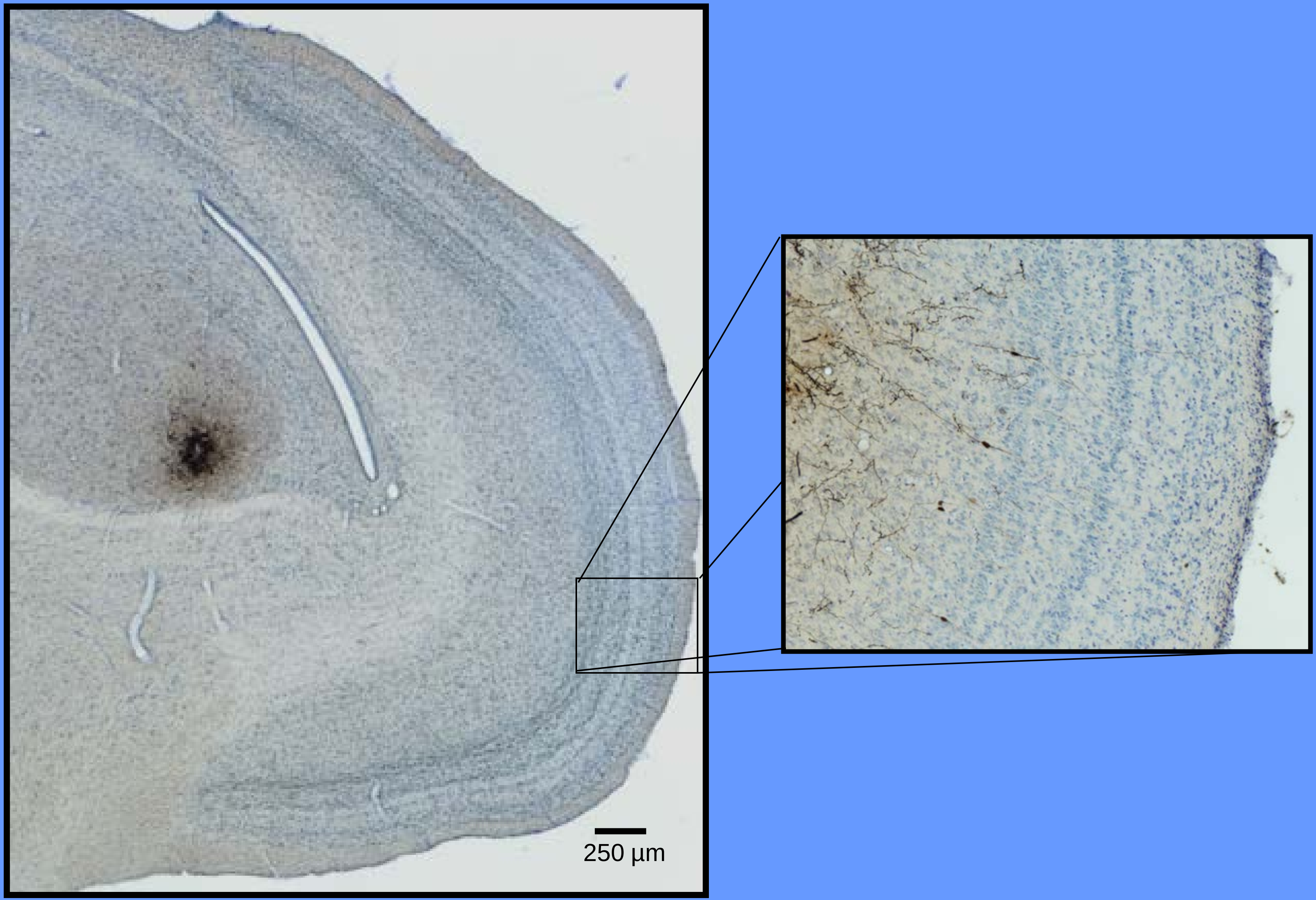
The instructive signal

- Operates in the ICX

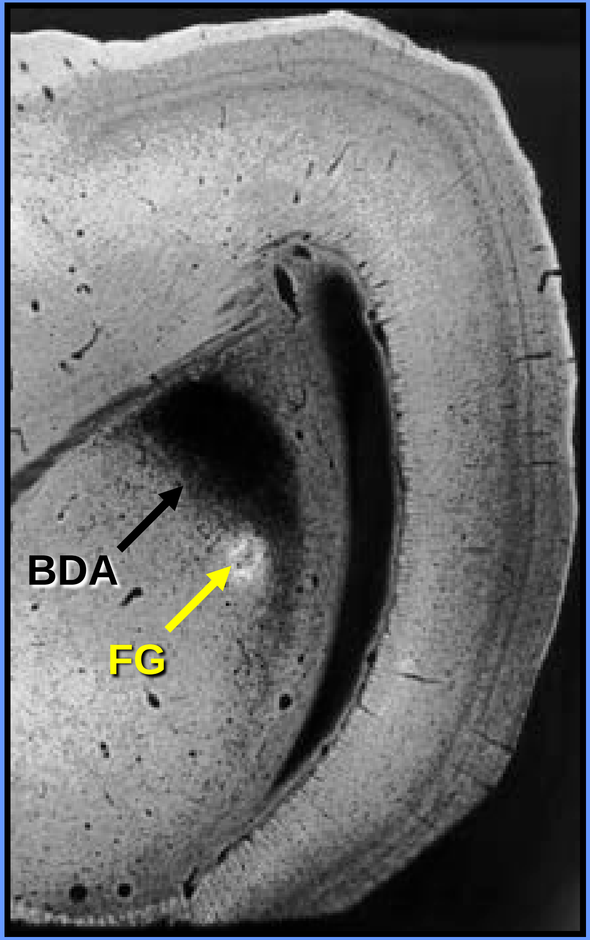
- Visually based

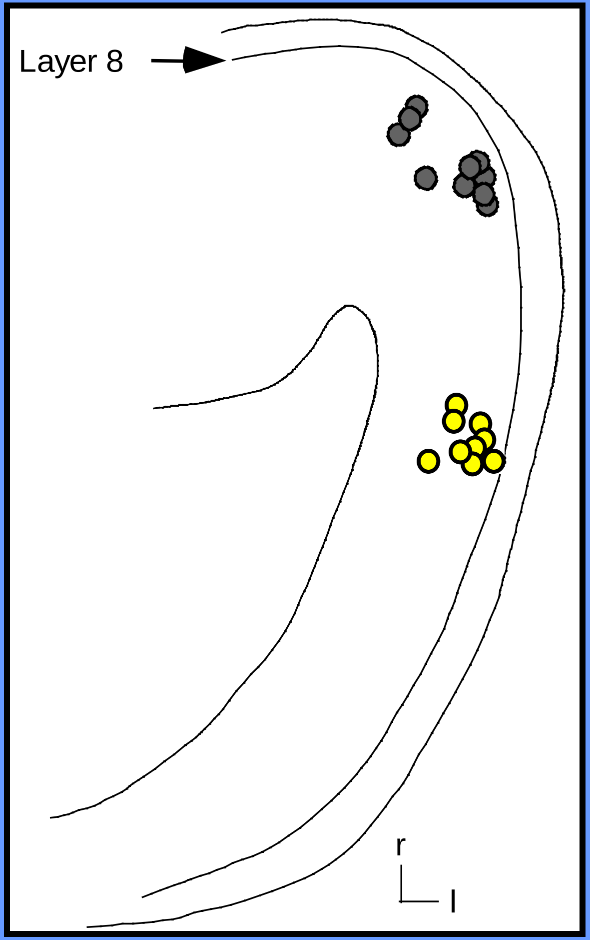
Where is the instructive signal coming from?

BDA injection site in ICX

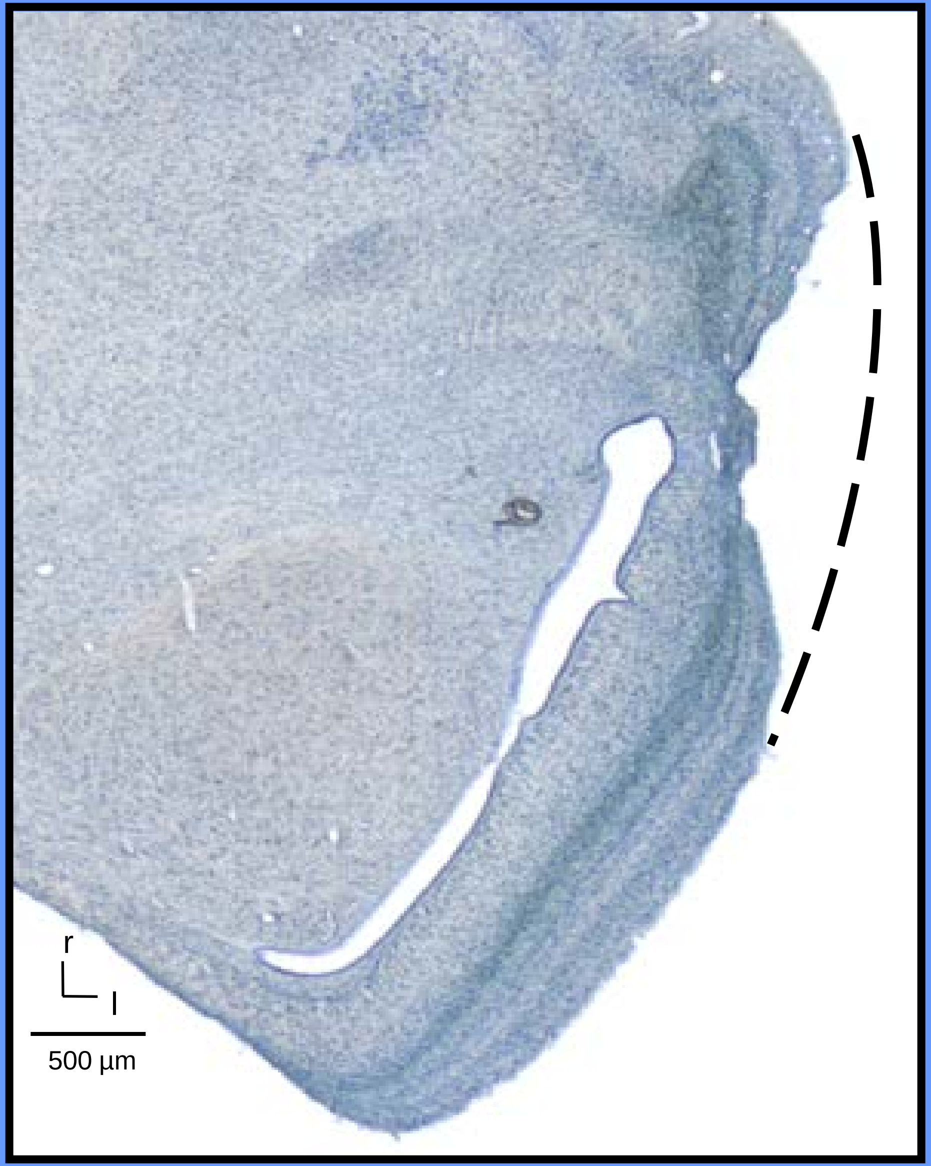


Topography of the OT-ICX projection



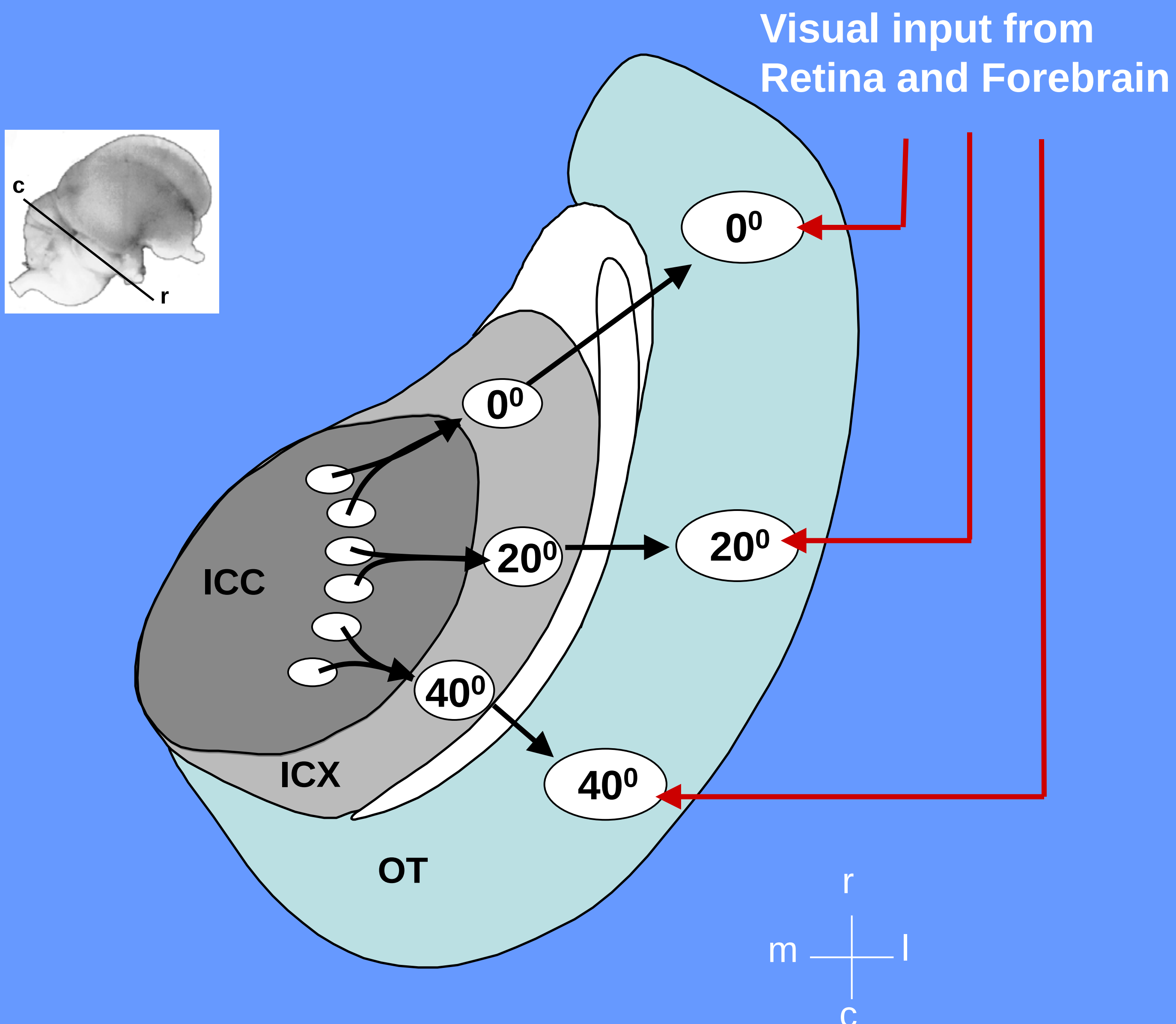


Restricted lesion of the optic tectum

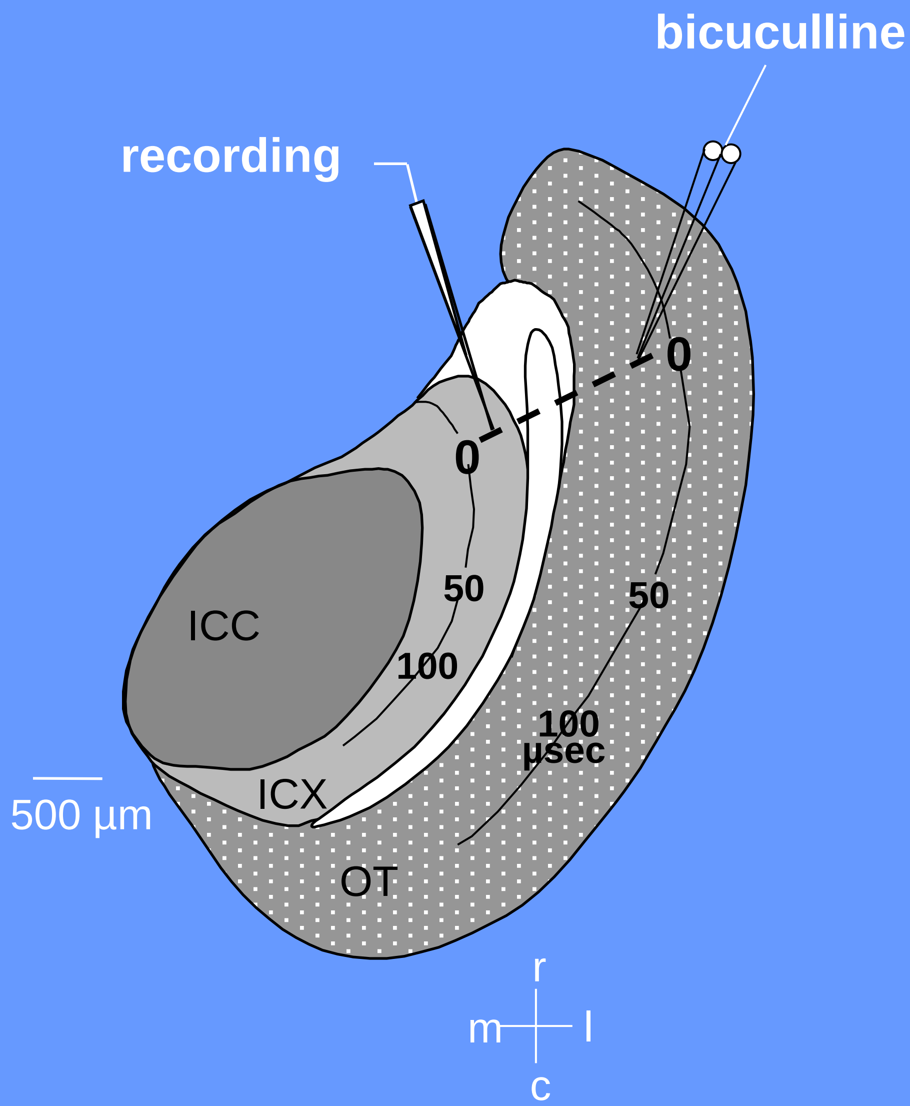


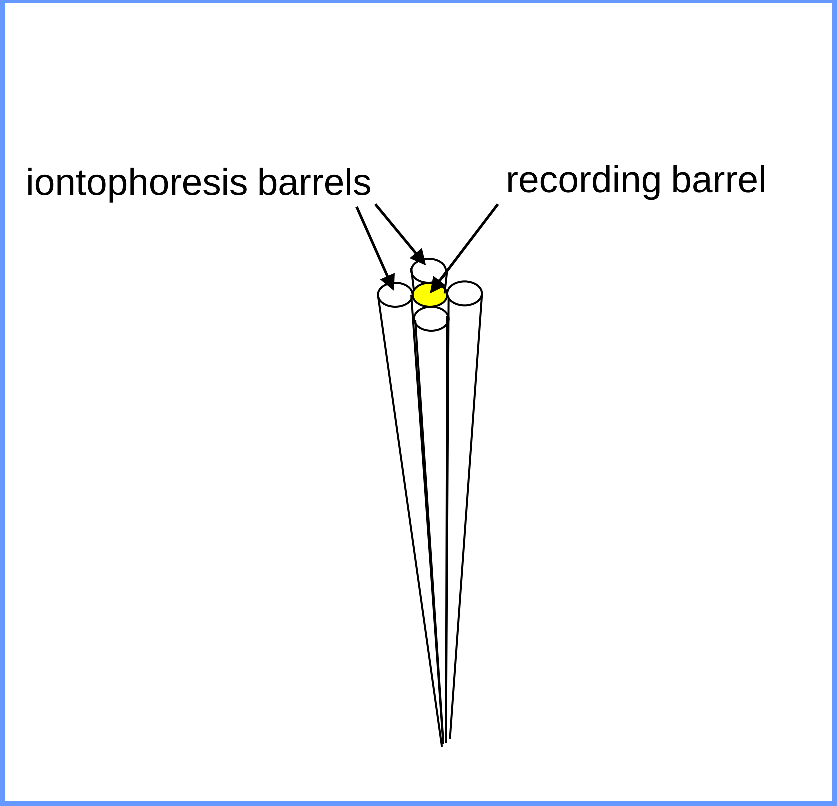
How can a visually based instructive signal act in an auditory structure?

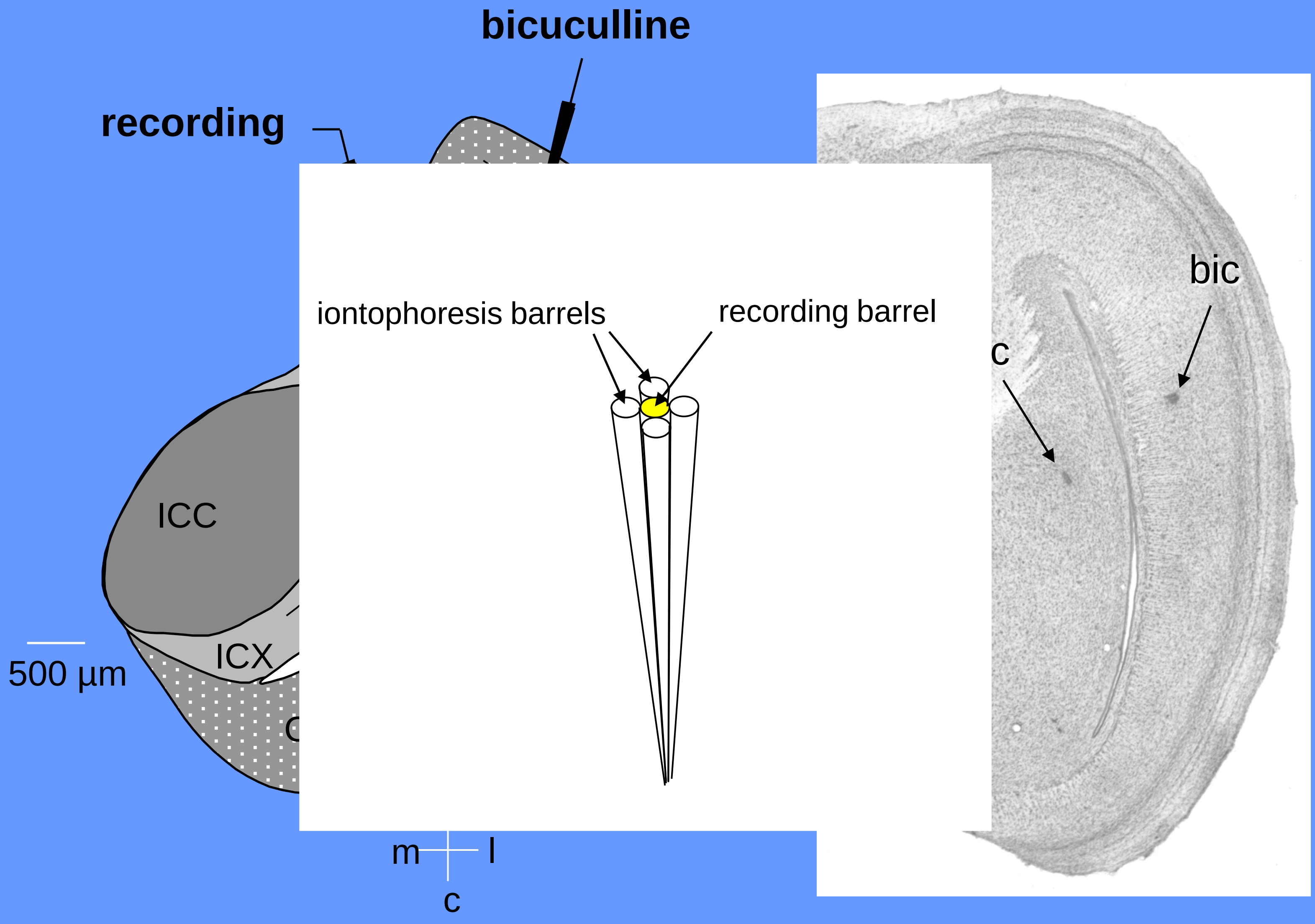
Horizontal section through the tectal lobe



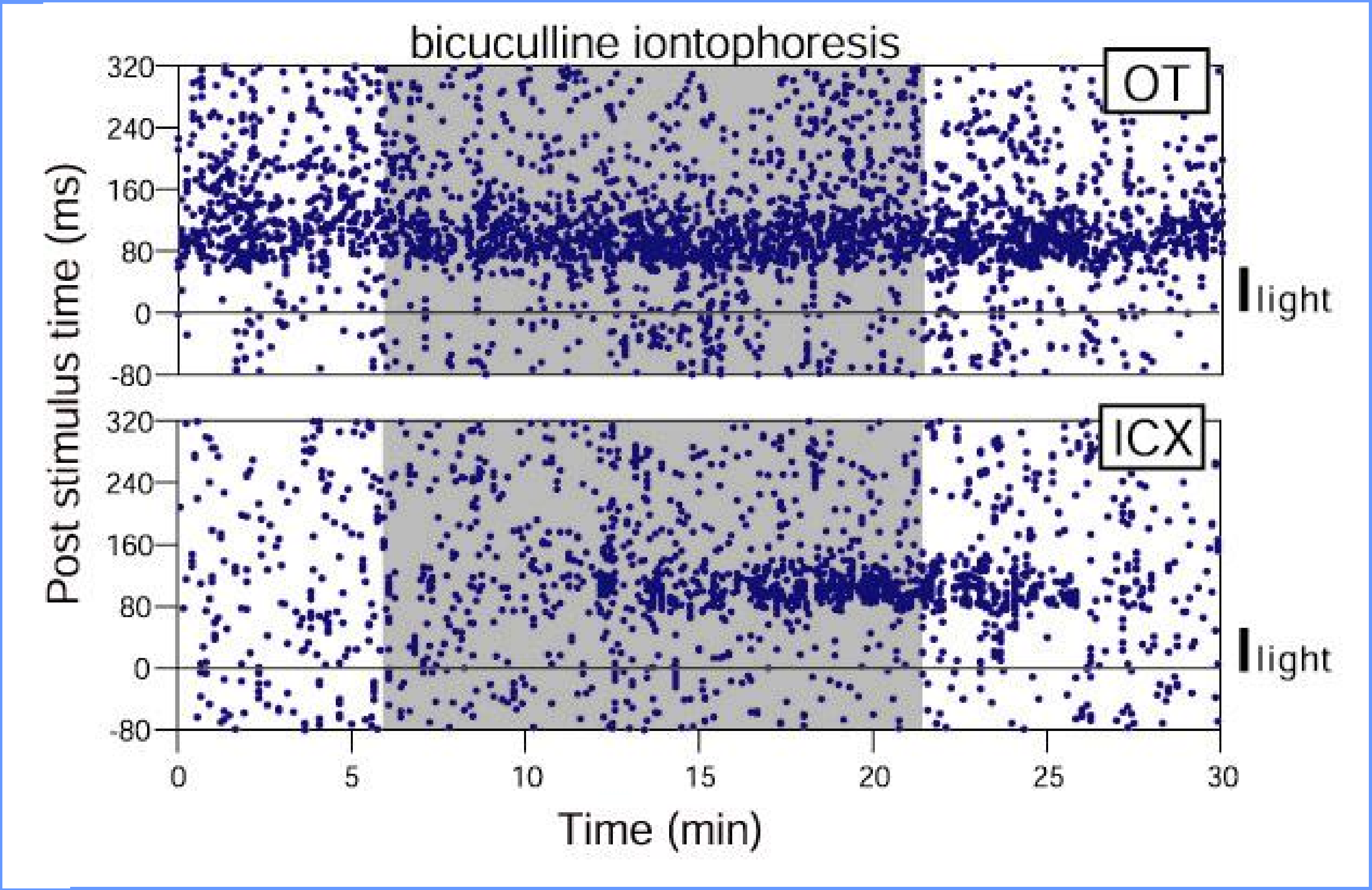
Experimental techniques



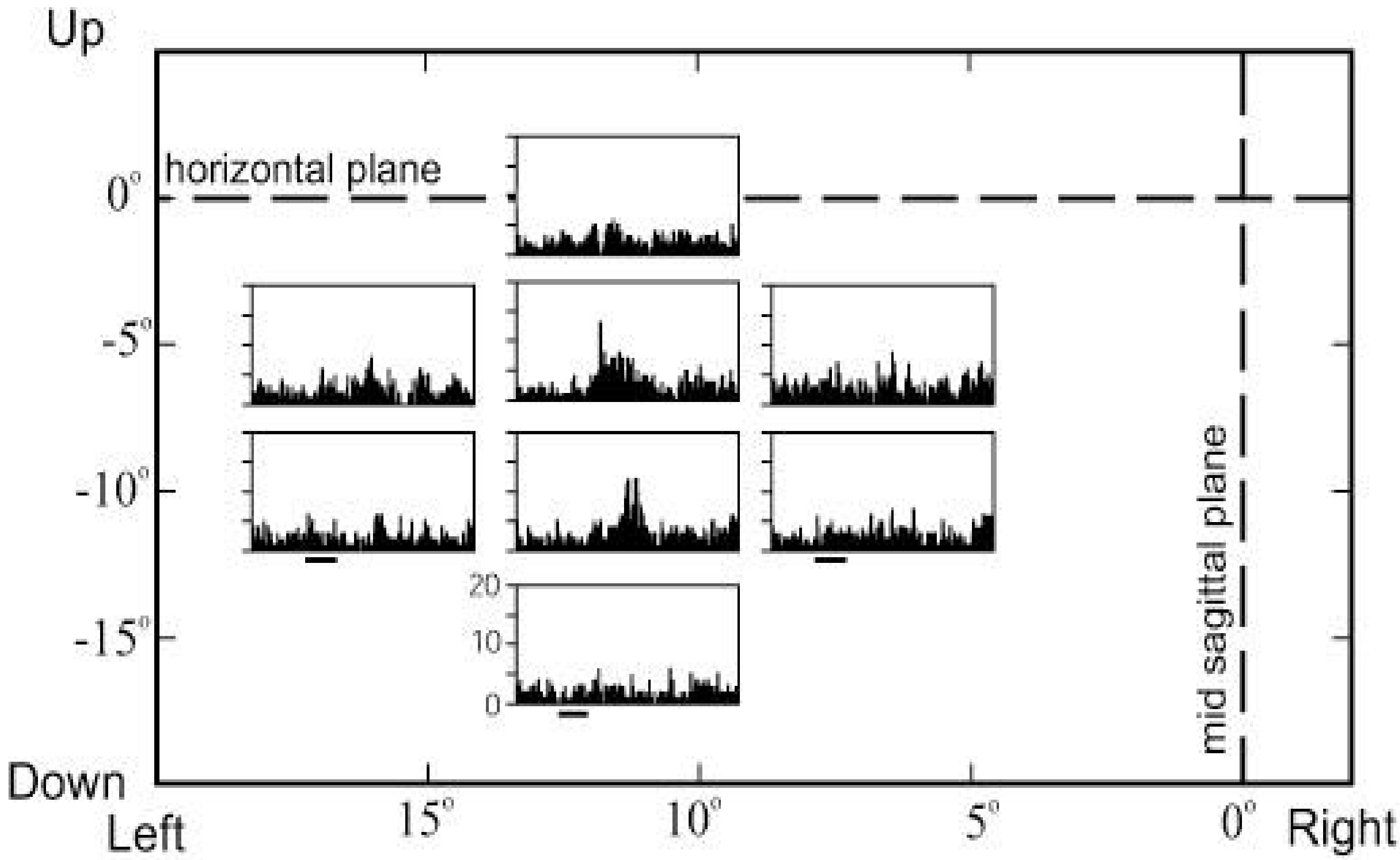


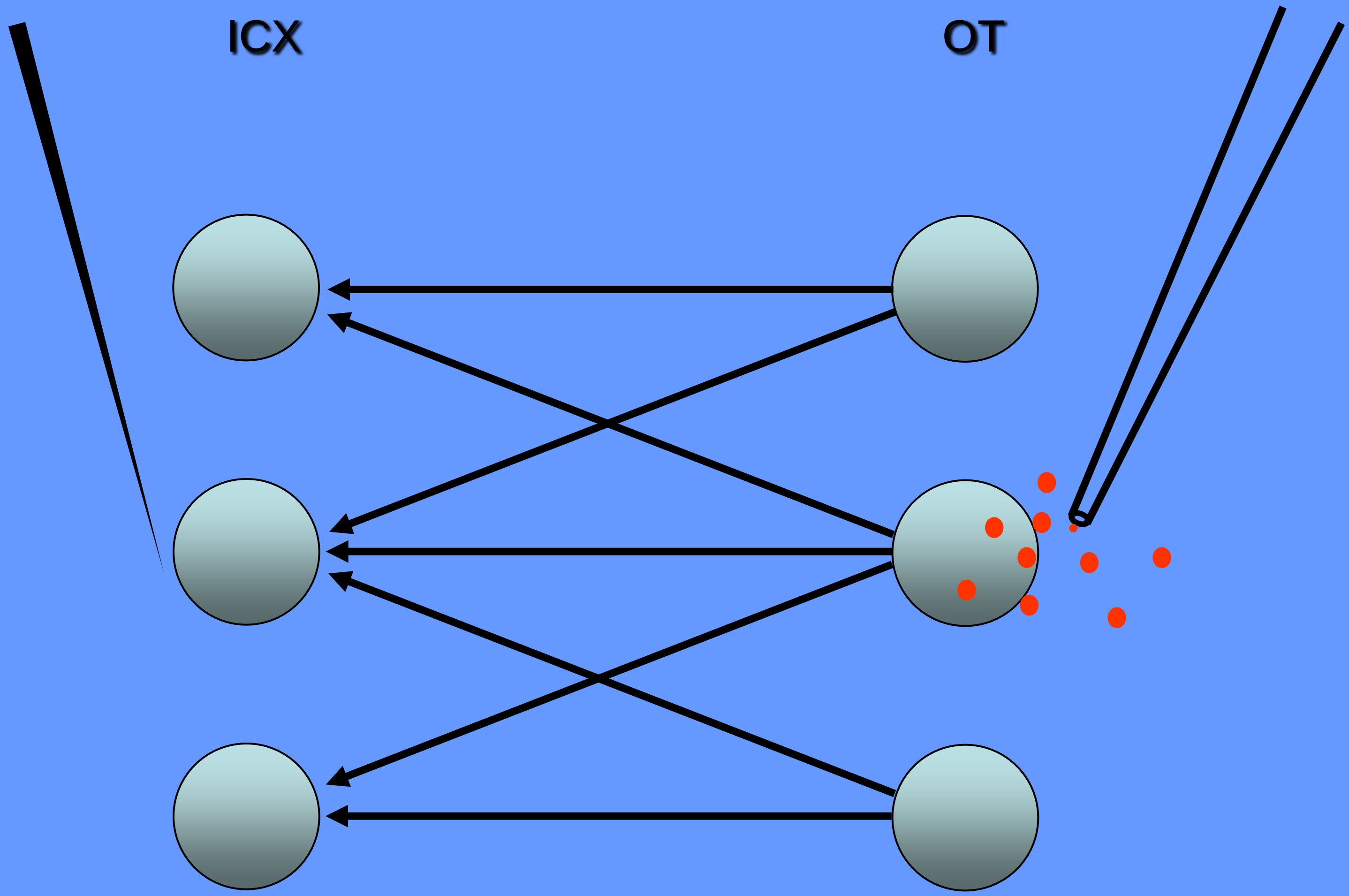

bicuculline
recording
ICC
ICX
500 µm
m
l
c
iontophoresis barrels
recording barrel
c
bic

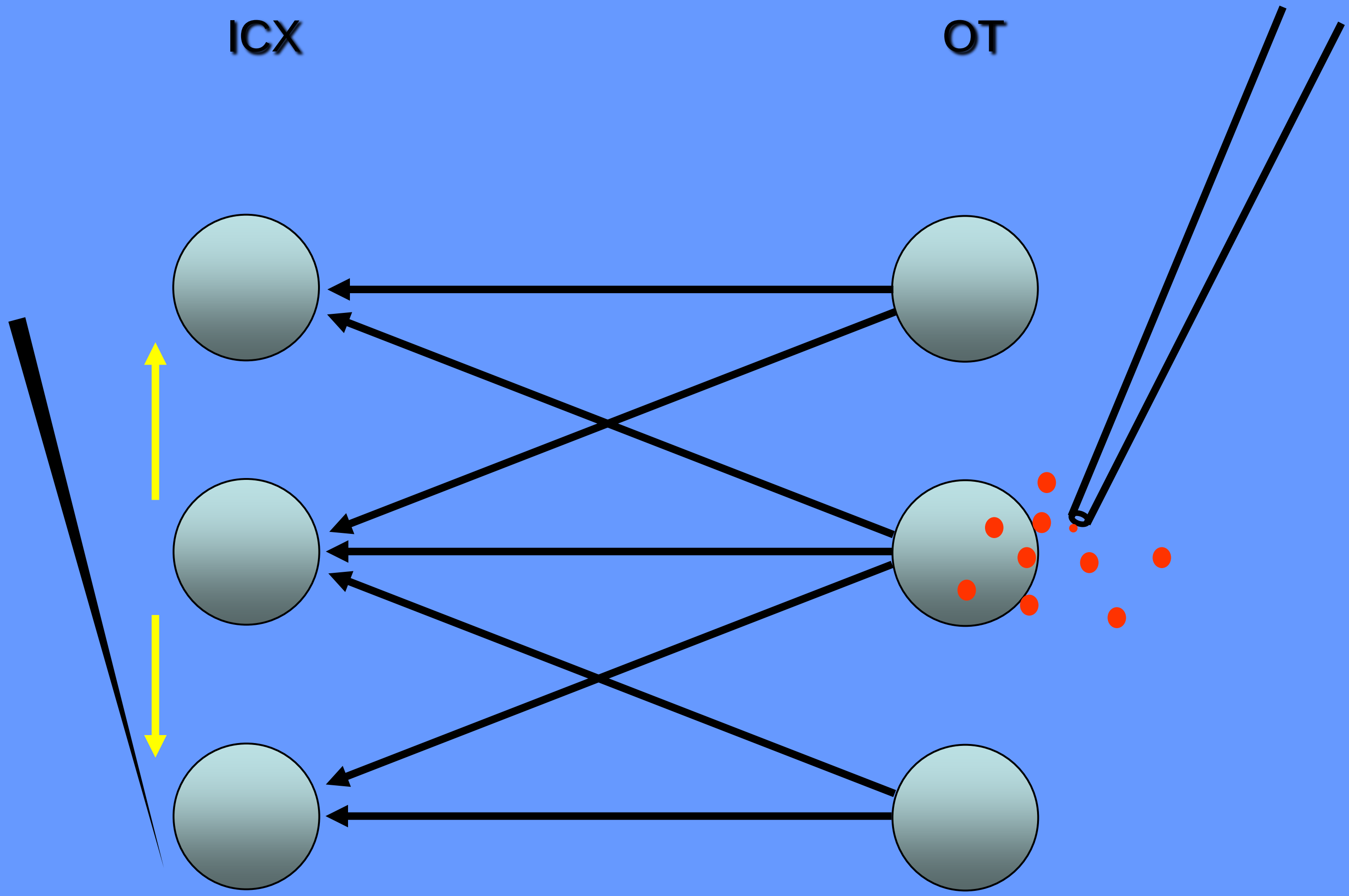
Light responses in the ICX

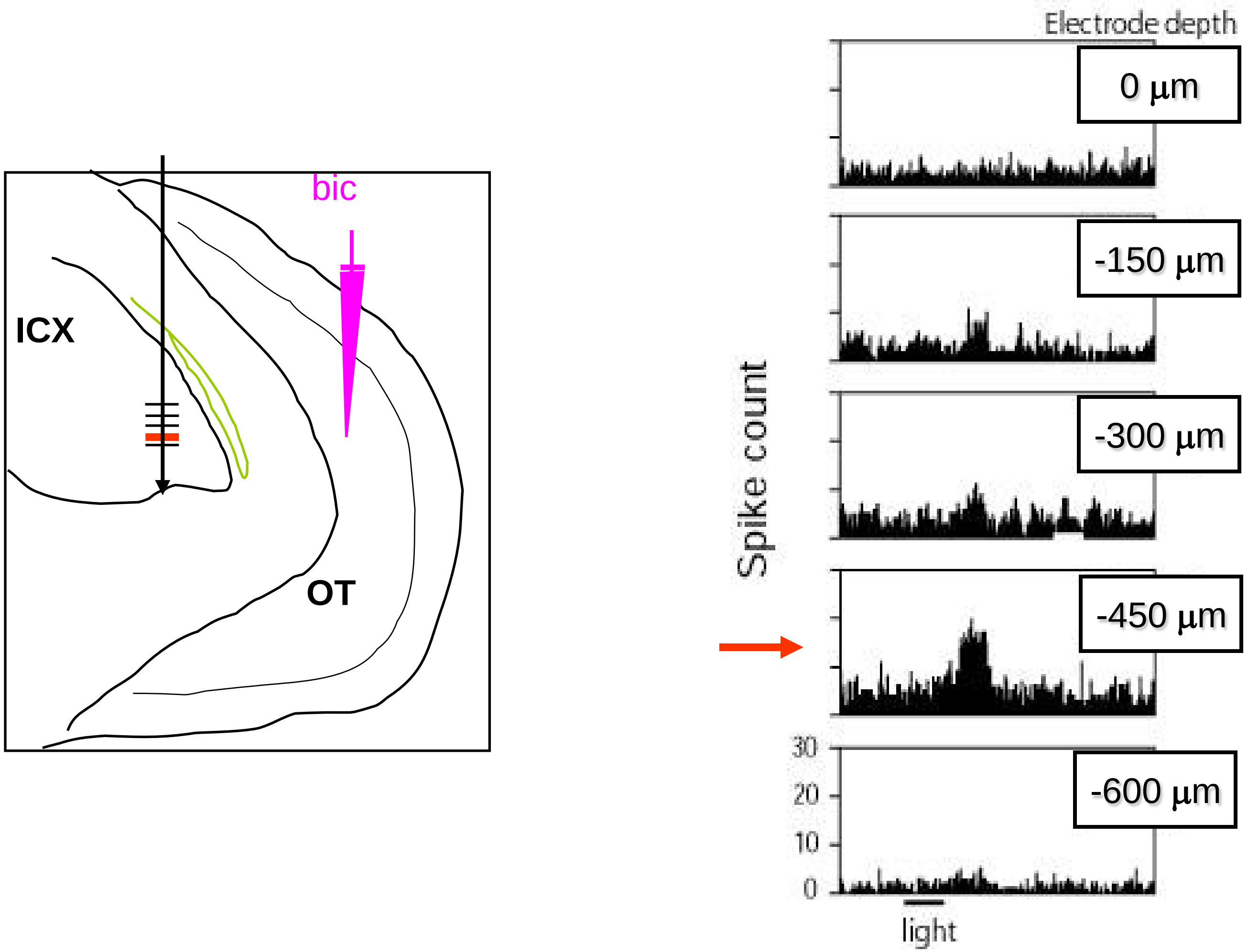


Visual Receptive Fields in the ICX

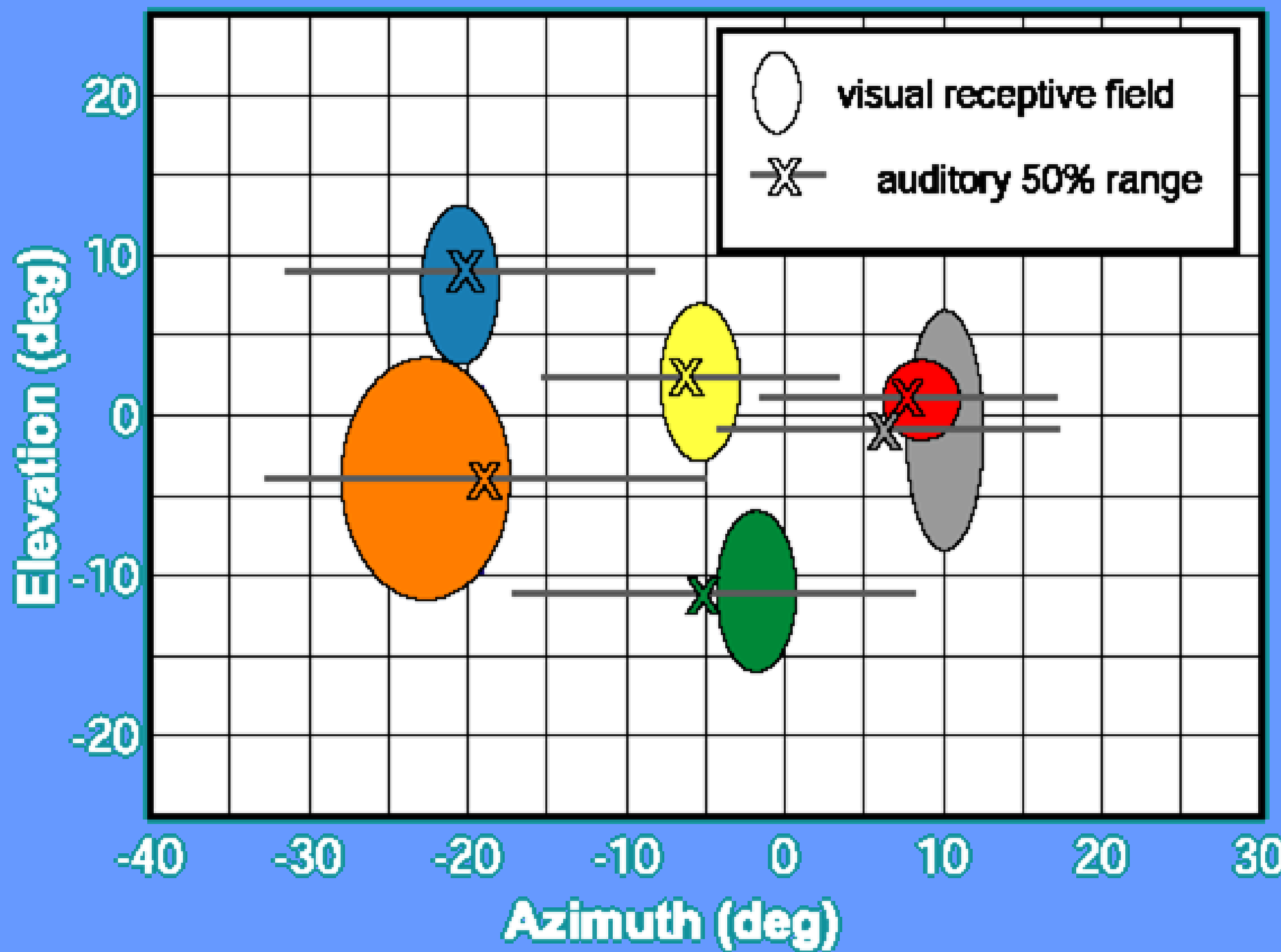



ICX
OT


ICX
OT



bic
ICX
OT
Spike count
Electrode depth
0 µm
-150 µm
-300 µm
-450 µm
-600 µm
30
20
10
0
light


visual receptive field
auditory 50% range
20
10
0
-10
-20
Elevation (deg)
-40
-30
-20
-10
0
10
20
30
Azimuth (deg)

Properties of visual responses in ICX

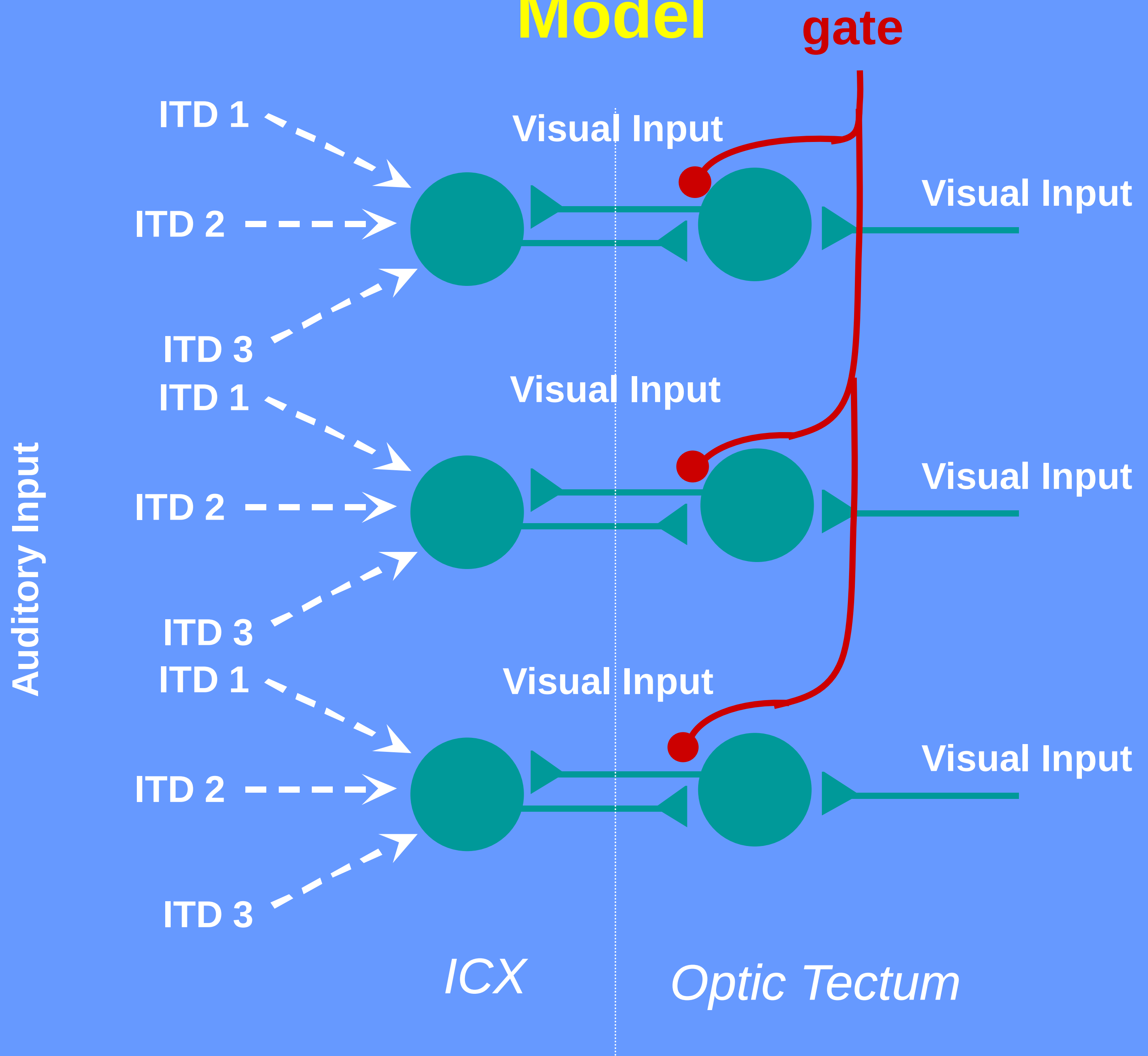
- Arrive from the OT

- Display spatially restricted visual receptive fields

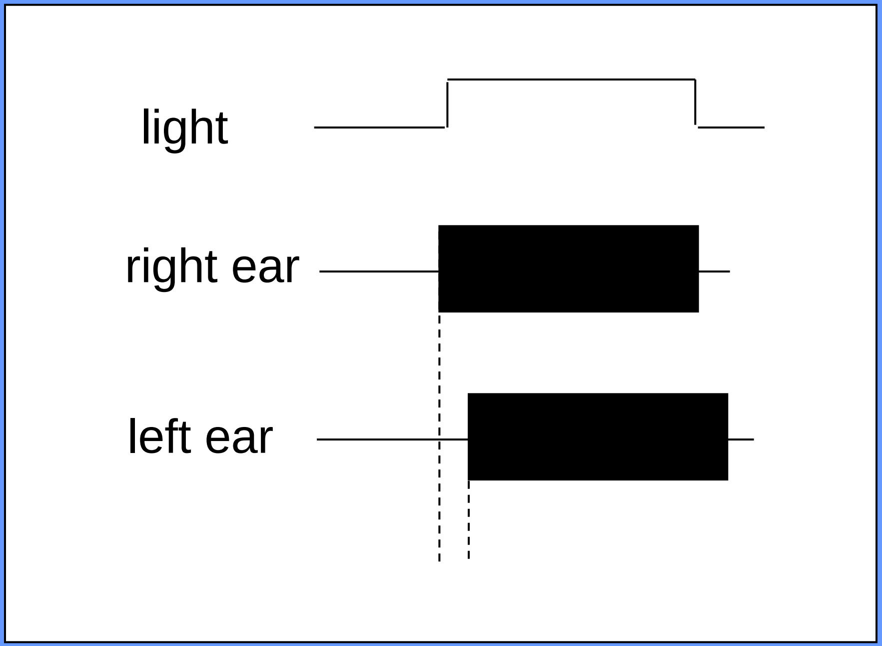
- Form a map of space

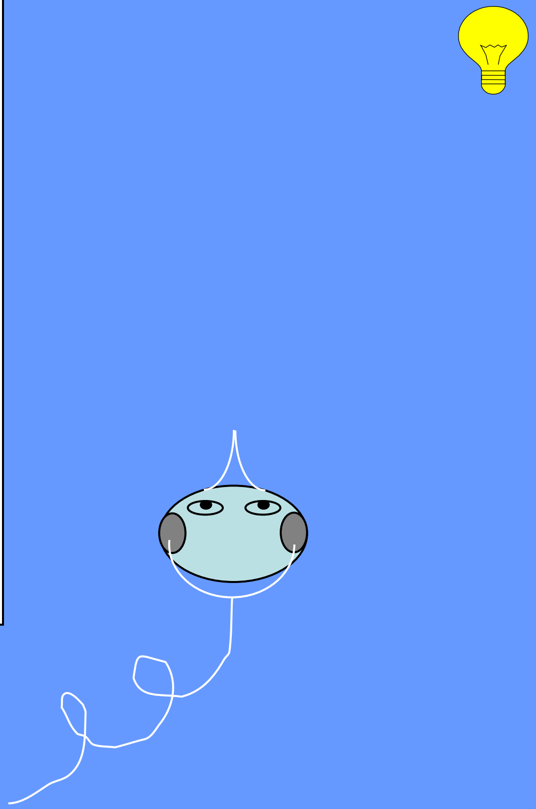
- Align with auditory spatial representation

Model

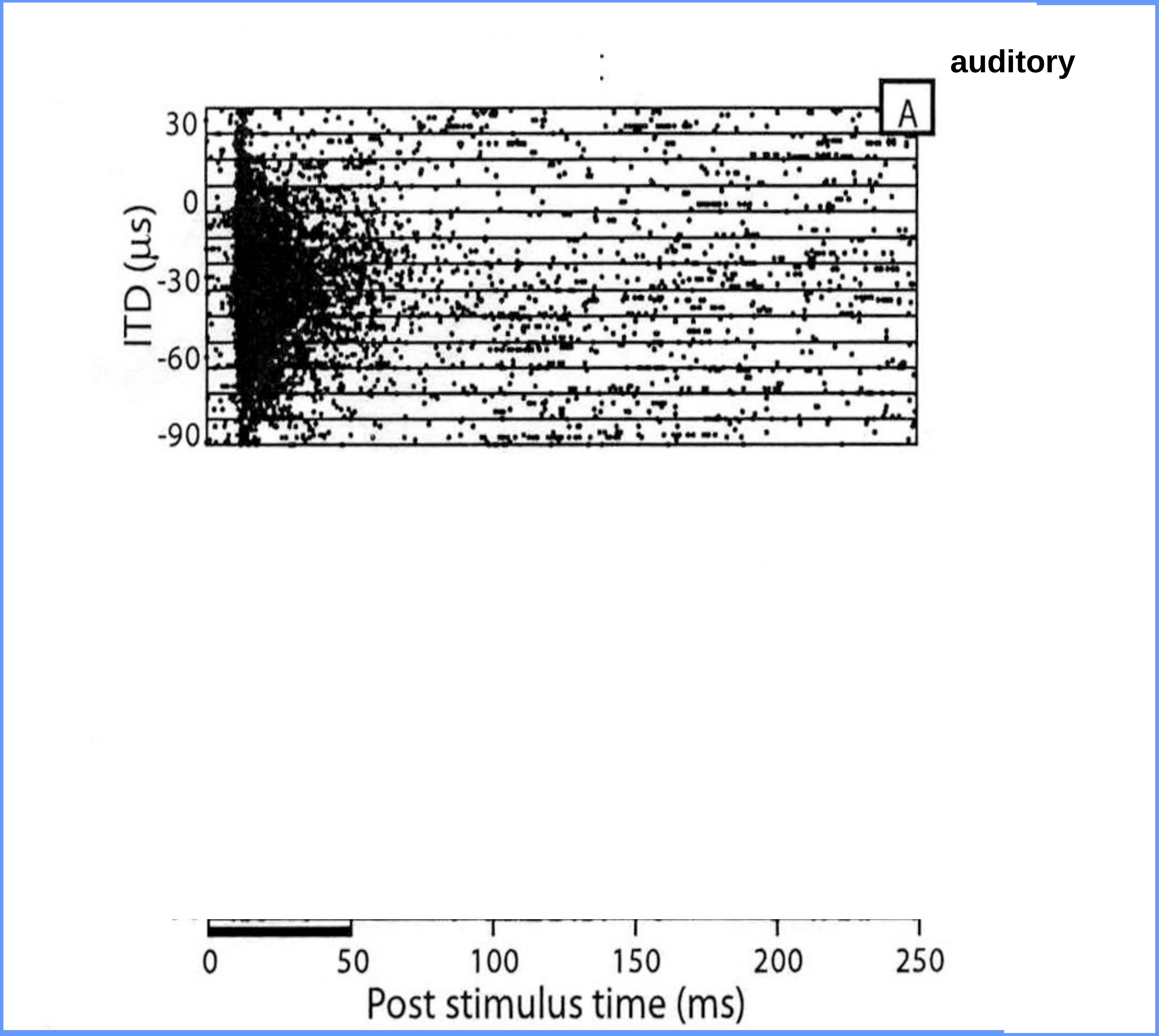

gate
Auditory Input
ITD 1
ITD 2
ITD 3
ITD 1
ITD 2
ITD 3
ITD 1
ITD 2
ITD 3
Visual Input
Visual Input
Visual Input
Visual Input
Visual Input
Visual Input
ICX
Optic Tectum

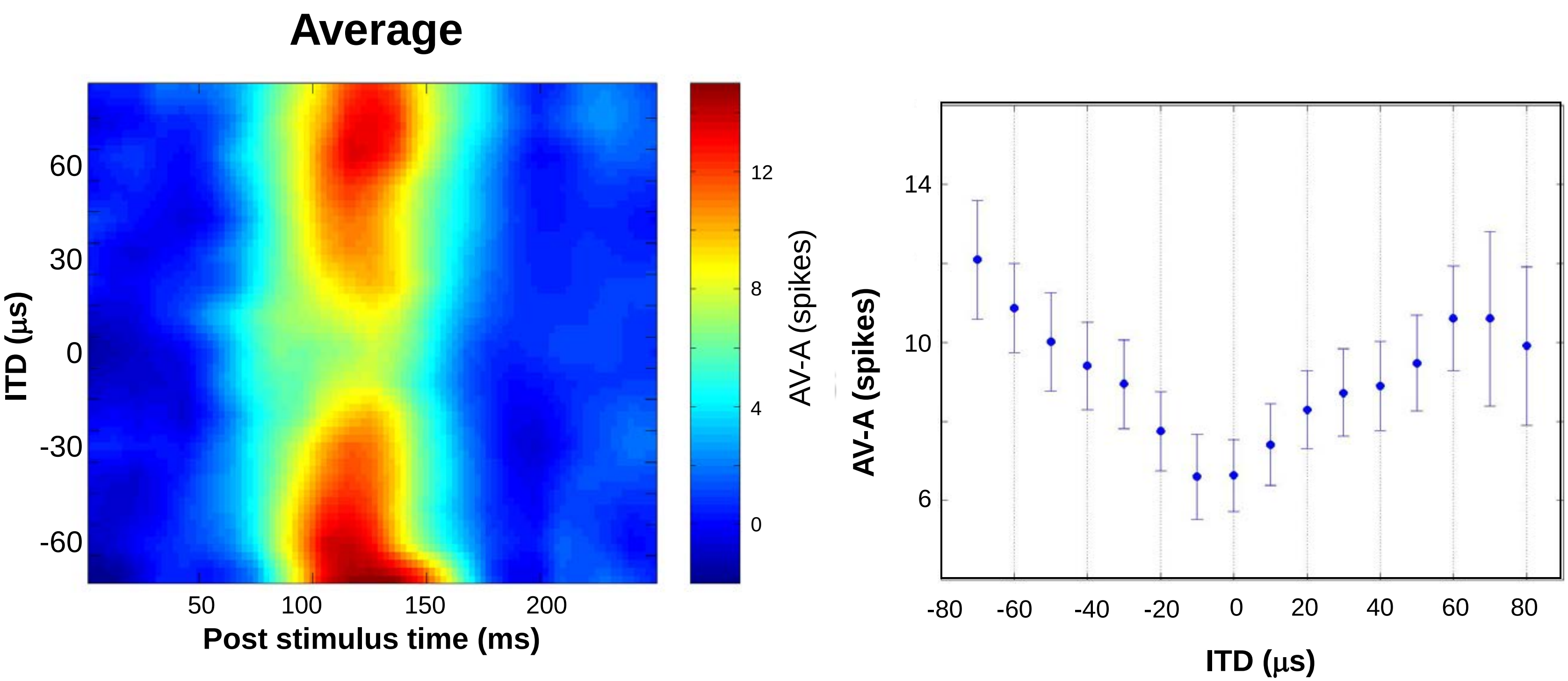
Bimodal Stimulus





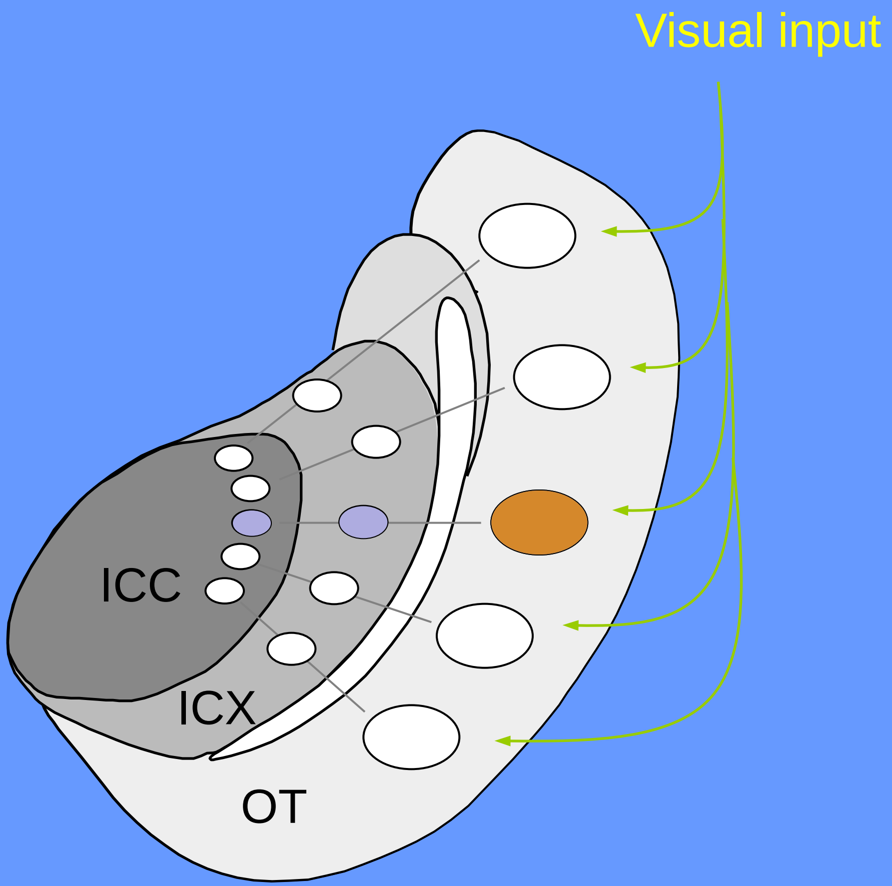
Visual and auditory interactions in the ICX




Average
60
30
0
-30
-60
ITD (µs)
50
100
150
200
Post stimulus time (ms)
12
8
4
0
AV-A (spikes)
14
10
6
AV-A (spikes)
-80
-60
-40
-20
0
20
40
60
80
ITD (µs)

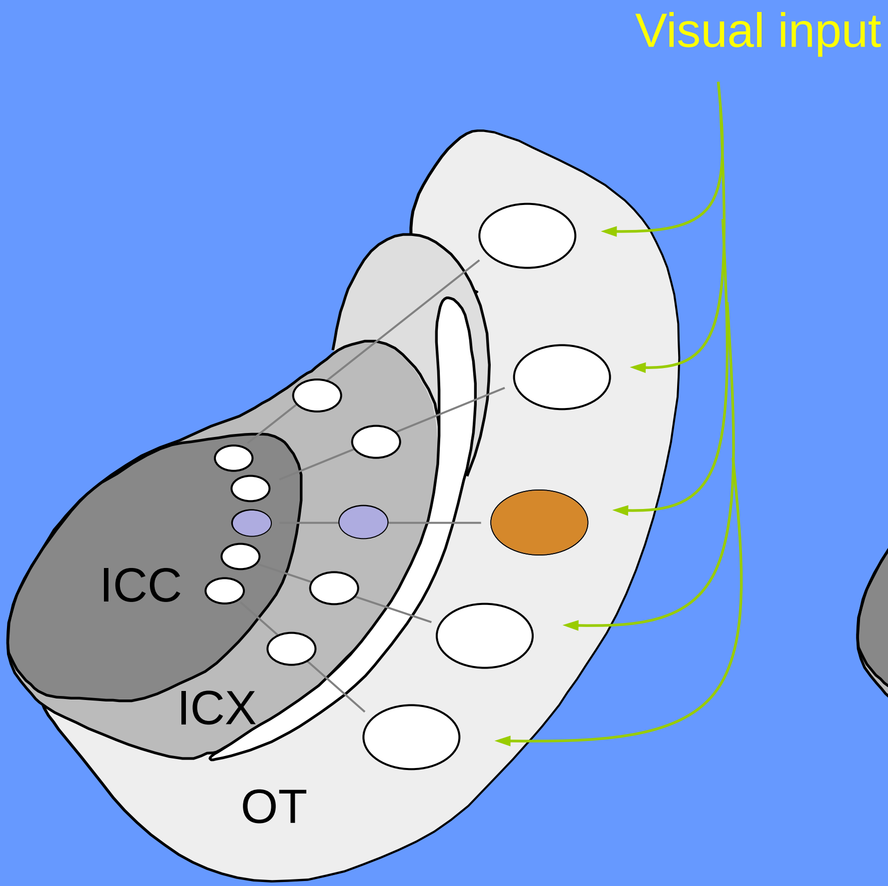
Bimodal stimulus

Normal

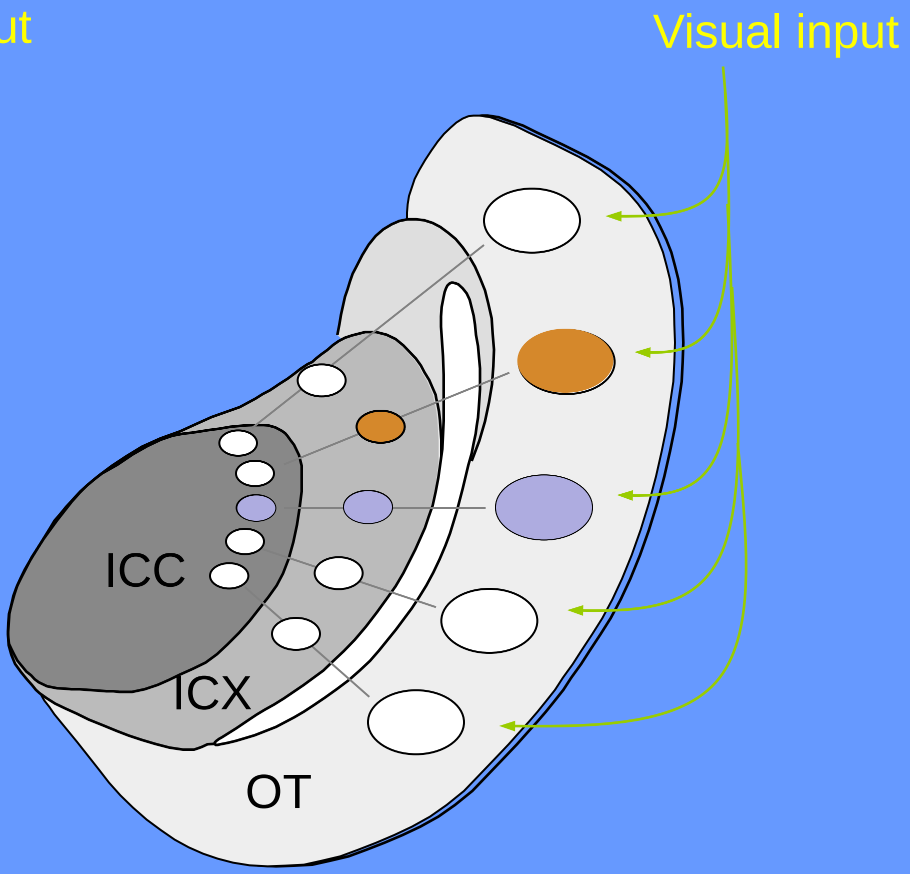


Bimodal stimulus

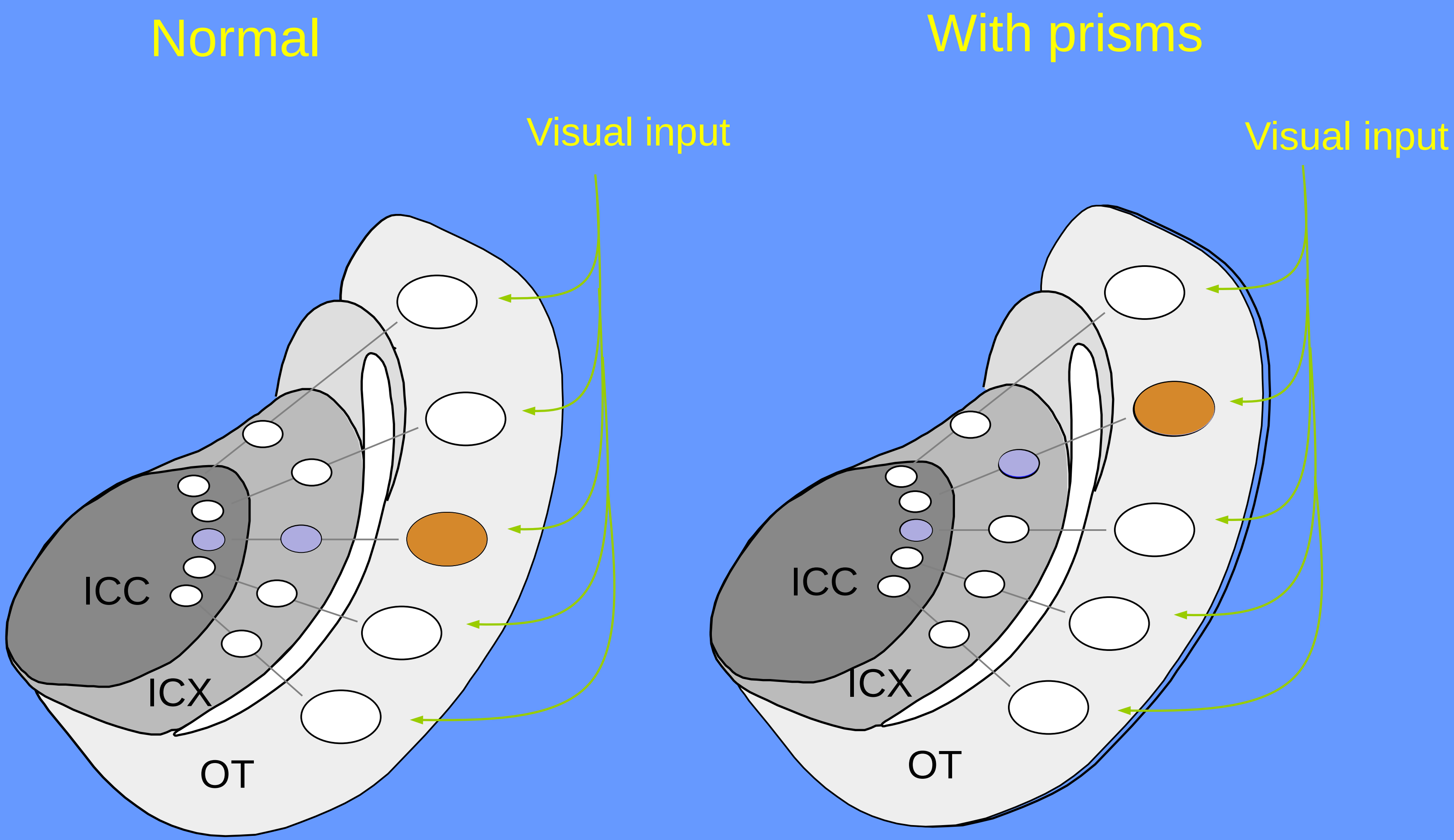
Normal



With prisms



Bimodal stimulus



Summary

- An inhibitory gate controls the flow of visual information into the auditory system

Summary

- An inhibitory gate controls the flow of visual information into the auditory system

- The visual signals are appropriate to serve as the instructive signal for auditory plasticity

- Eric Knudsen
  Daniel Feldman
  Michael Brainard
  Will Debello
  Peter Hyde
  Brie Linkenhoker
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