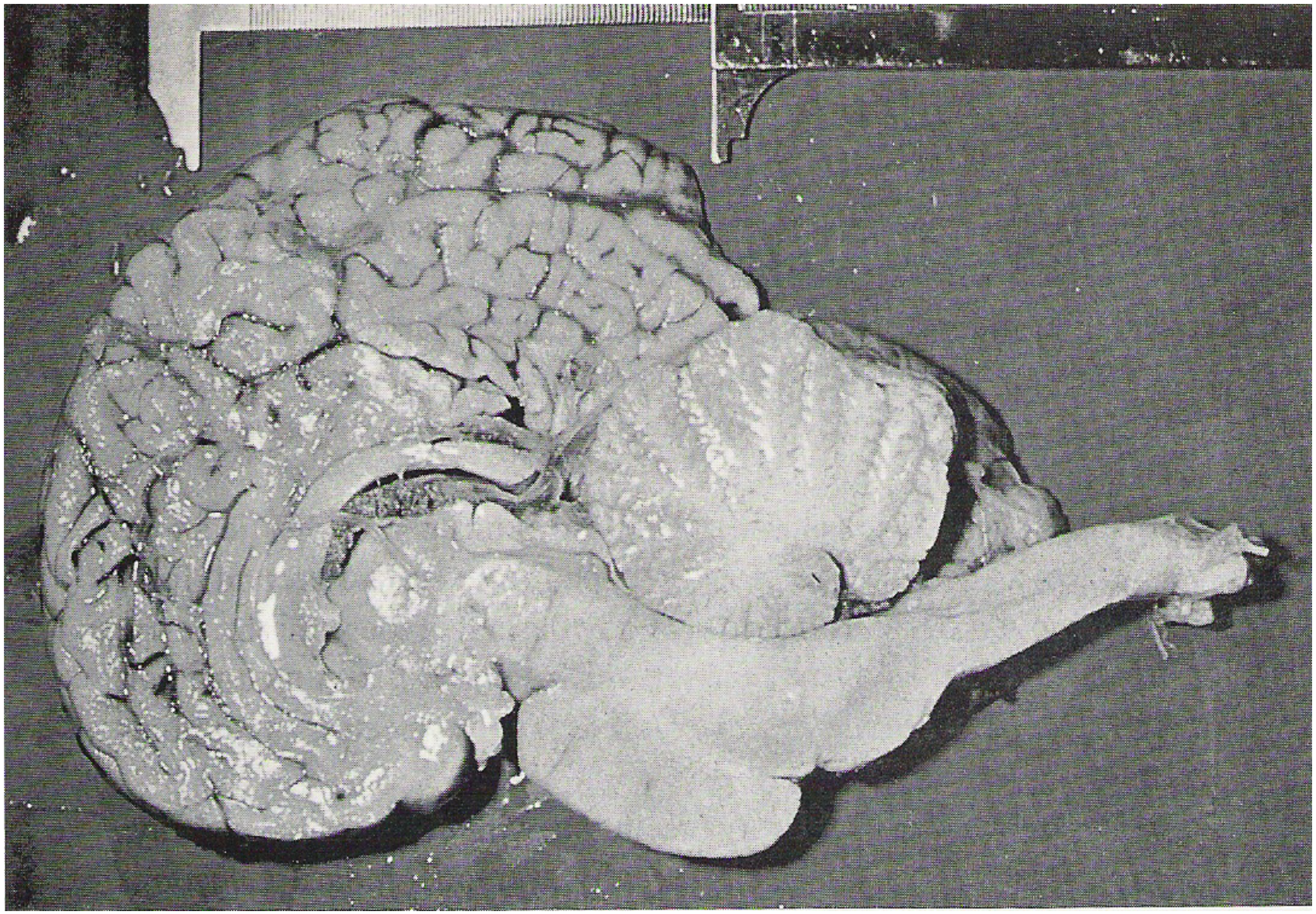
Cetacean Brains

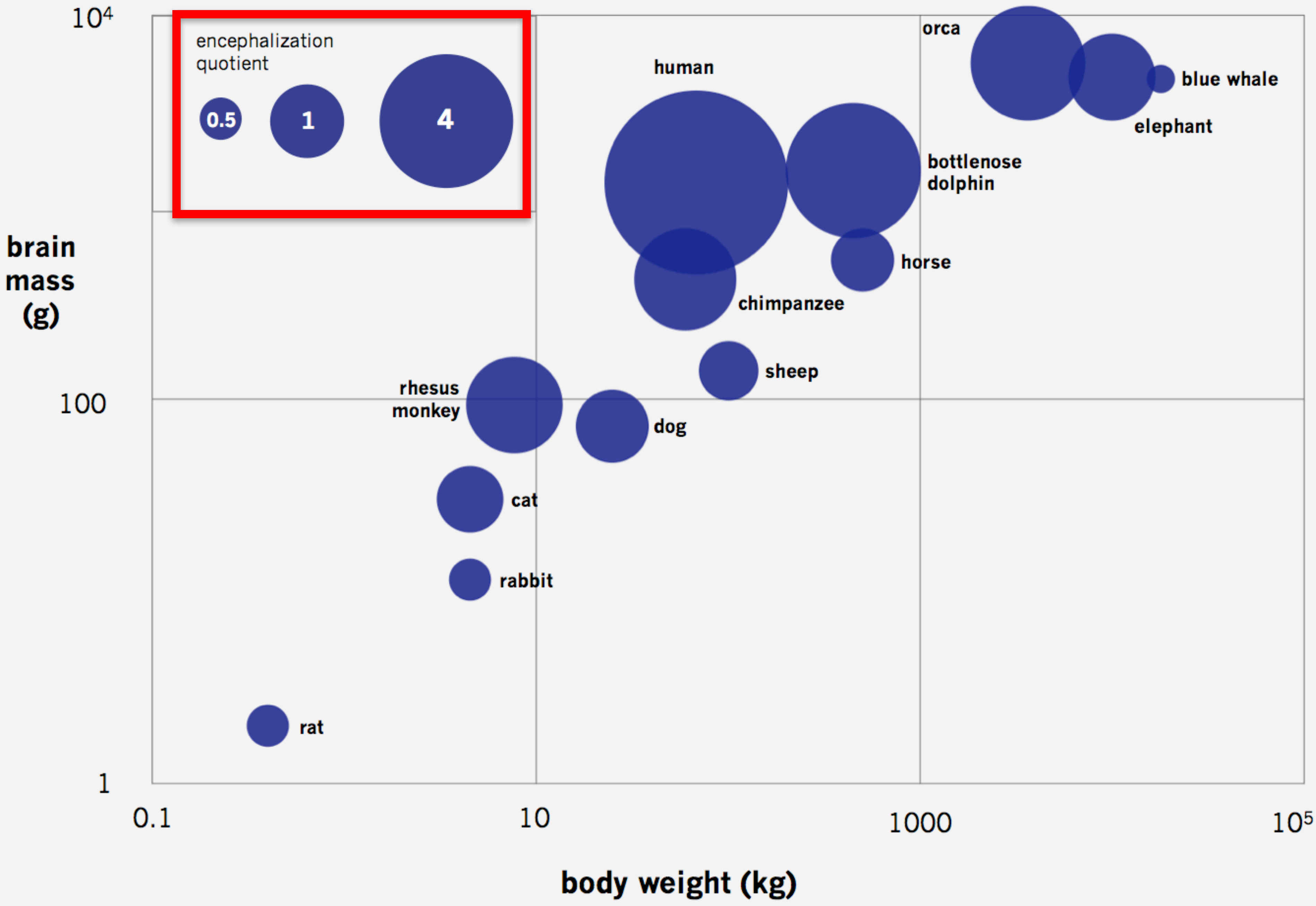


EQ -- Encephalization Quotient

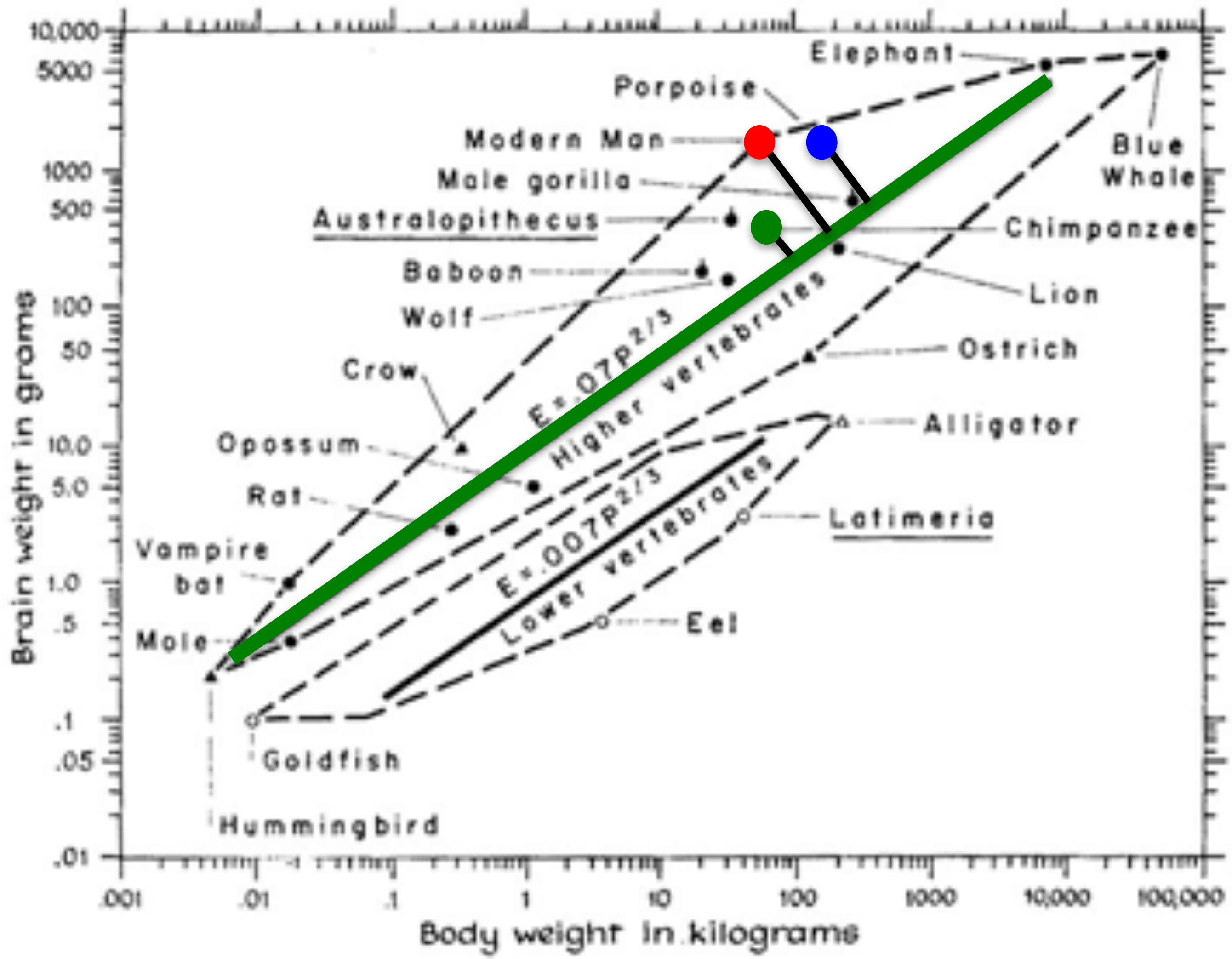
EQ = Actual brain mass / Expected brain mass

Where "expected" = $0.12 \times (\text{Body mass})^{2/3}$

Species	Encephalization quotient (EQ)[1]
Human	7.44[1]
Bottlenose dolphin	5.31[2]
Orca	2.57
Chimpanzee	2.48
Rhesus monkey	2.09
Elephant	1.87
Whale	1.76
Dog	1.17
Cat	1.00
Horse	0.86
Sheep	0.81
Mouse	0.50
Rat	0.40
Rabbit	0.40


encephalization quotient
0.5
1
4
brain mass (g)
10^4
100
1
0.1
10
1000
10^5
body weight (kg)
orca
blue whale
elephant
human
bottlenose dolphin
horse
chimpanzee
sheep
rhesus monkey
dog
cat
rabbit
rat

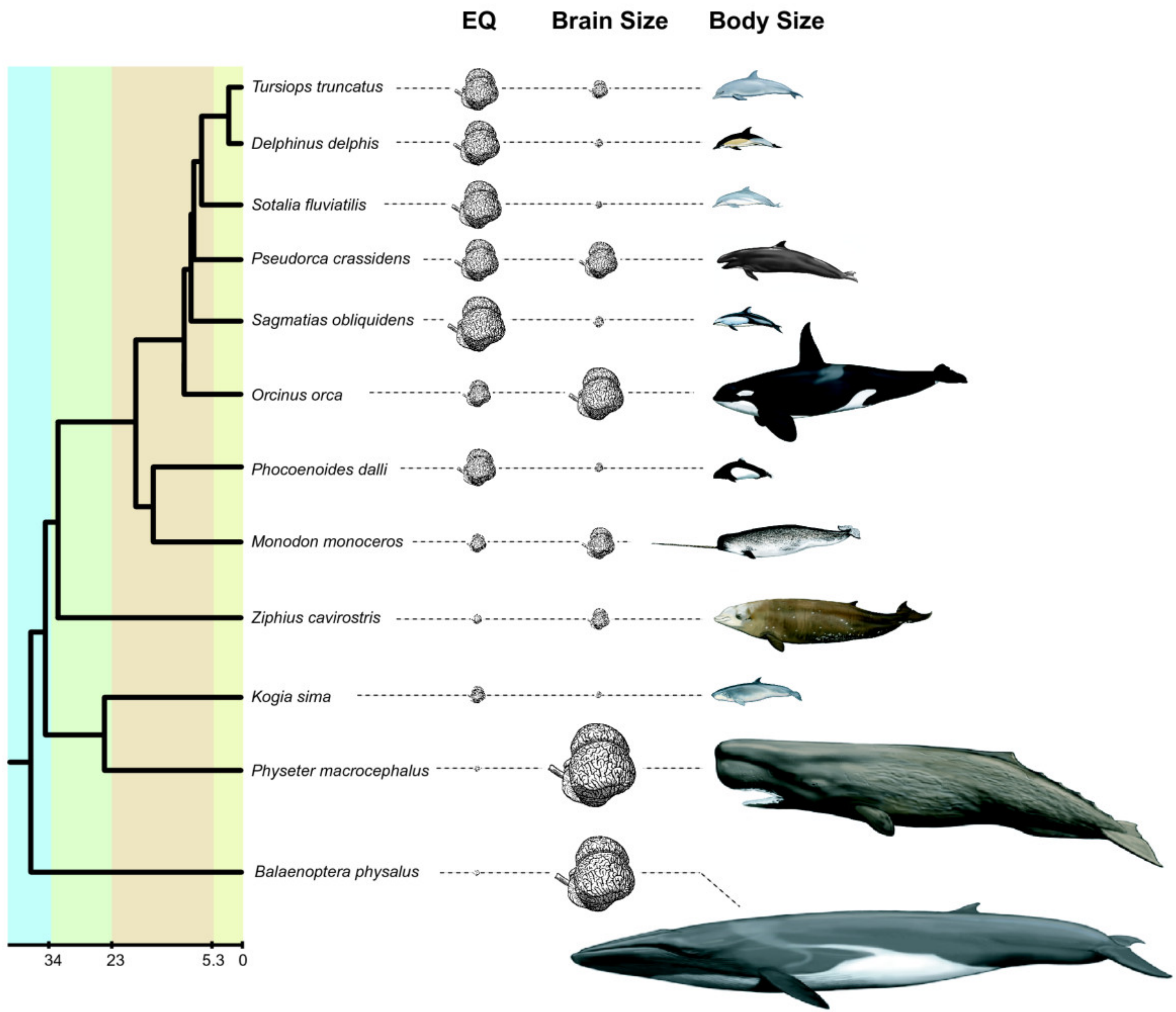
EQ -- Encephalization Quotient



Chimp

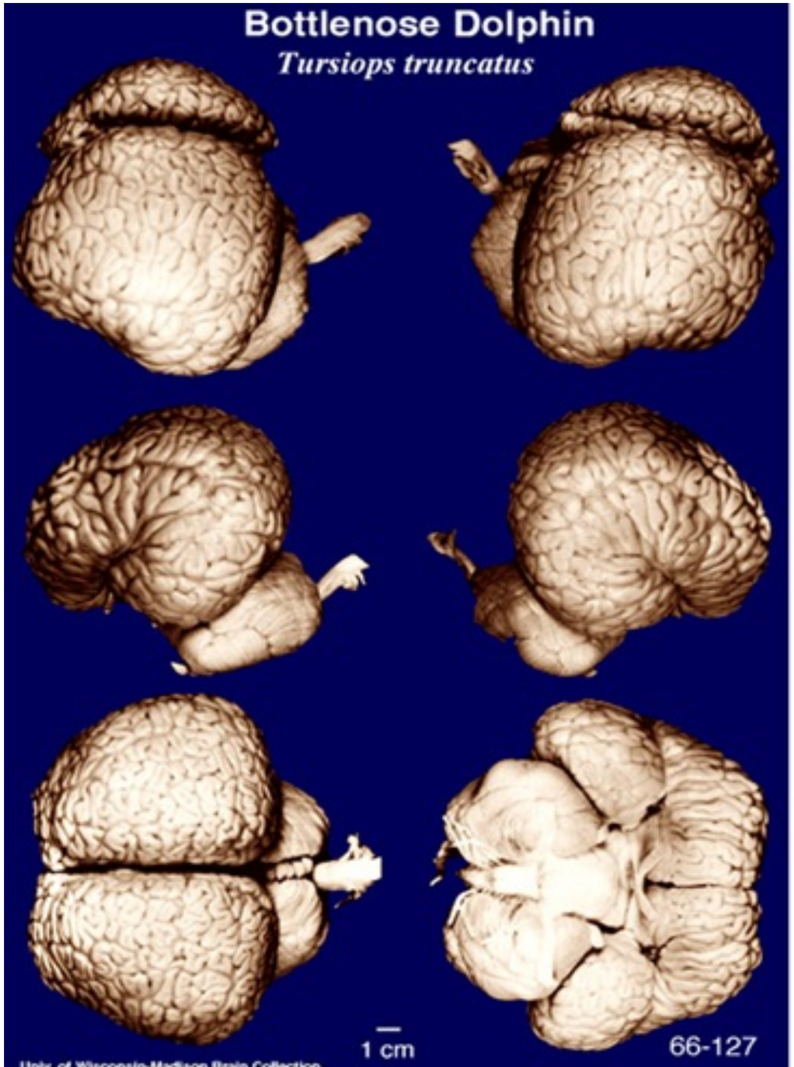
Human

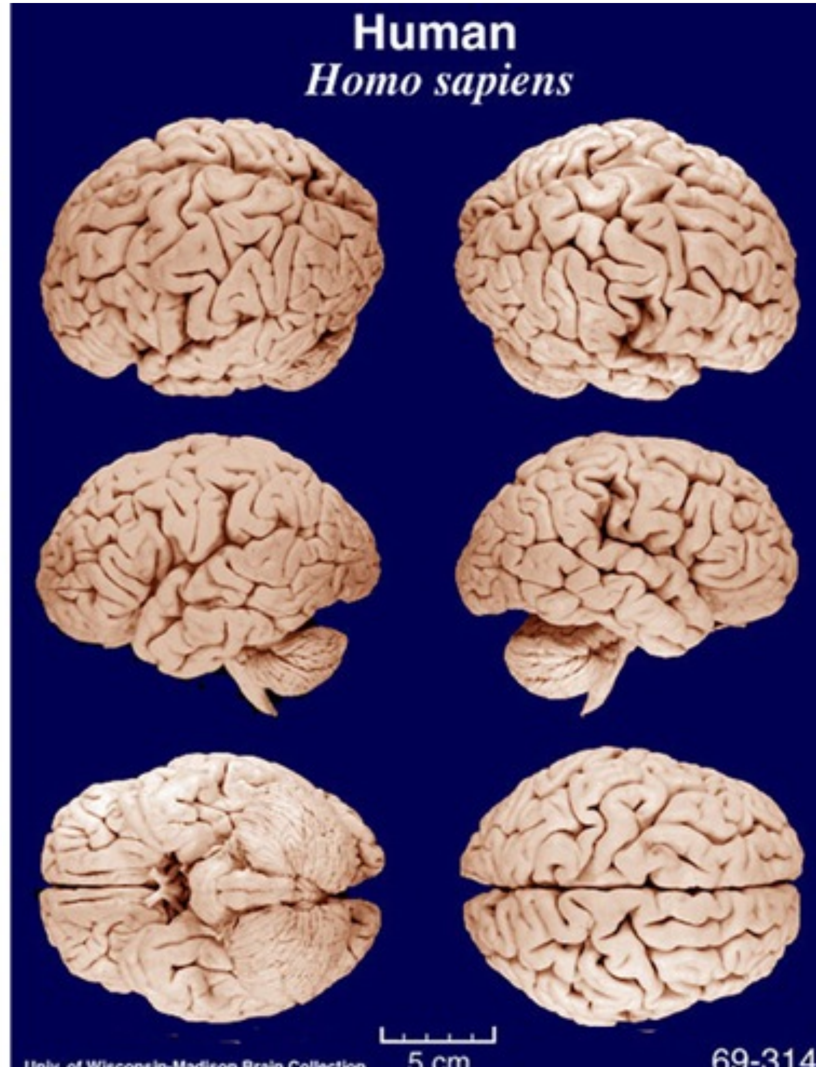
Dolphin



EQ
Brain Size
Body Size
Tursiops truncatus
Delphinus delphis
Sotalia fluviatilis
Pseudorca crassidens
Sagmatias obliquidens
Orcinus orca
Phocoenoides dalli
Monodon monoceros
Ziphius cavirostris
Kogia sima
Physeter macrocephalus
Balaenoptera physalus
34
23
5.3
0

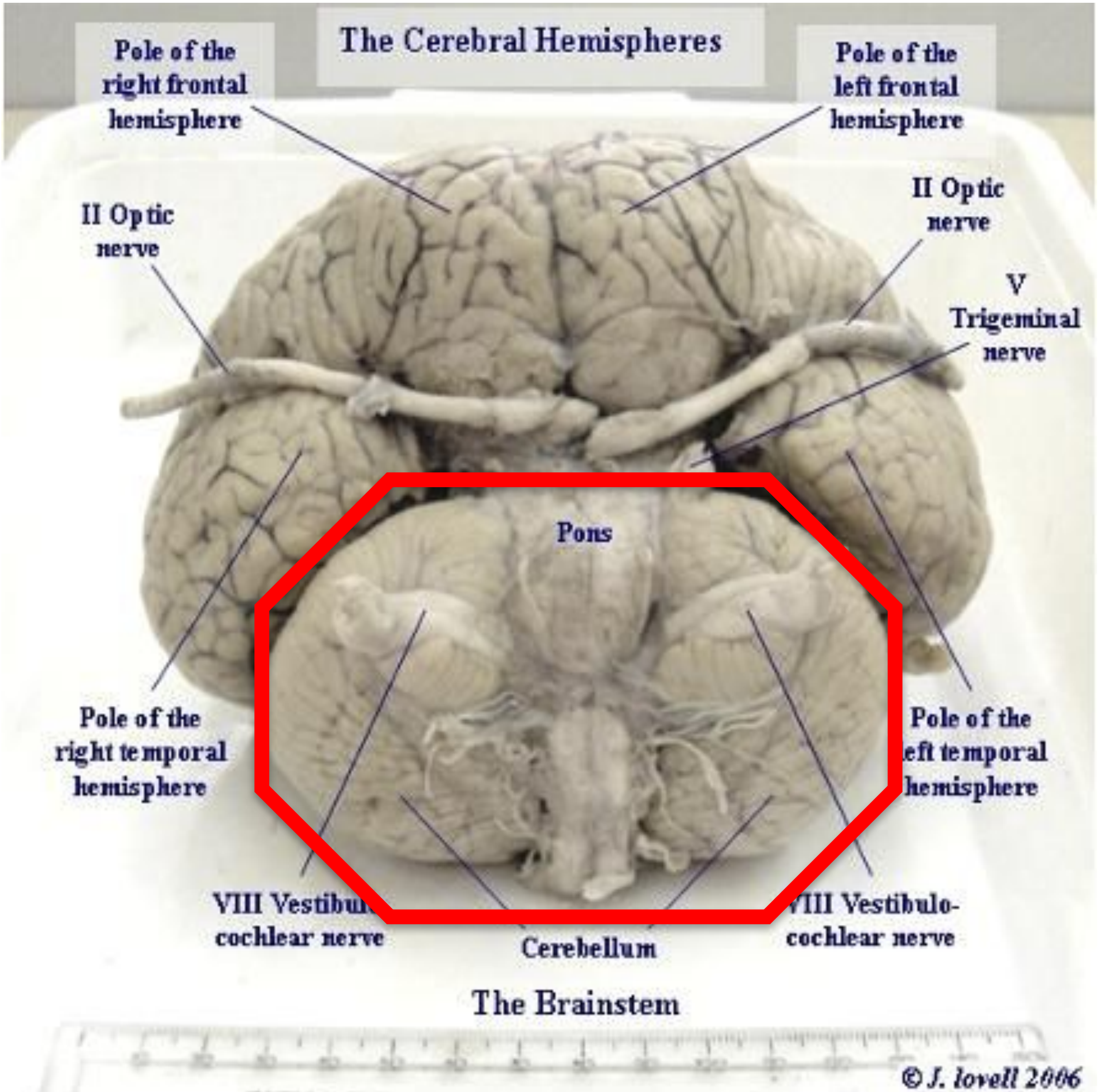
The Bottlenose Dolphin Brain

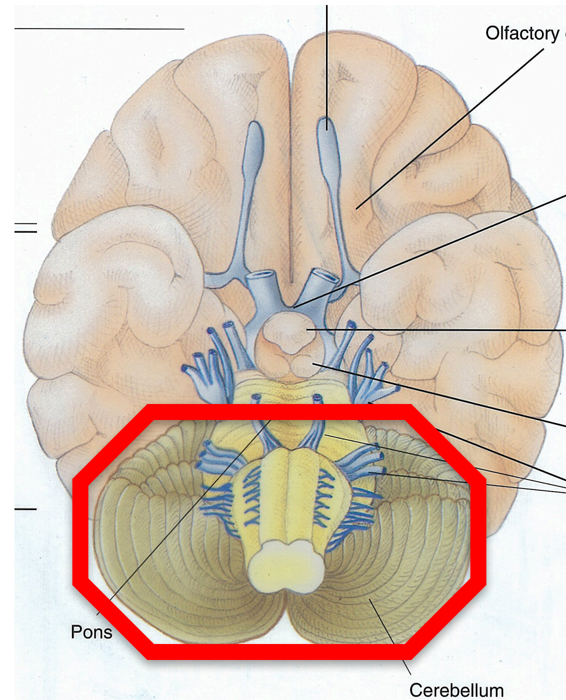




Globular shape

The Cerebellum ~ 15% (esp area for face)





Human ~11%

Brain Development

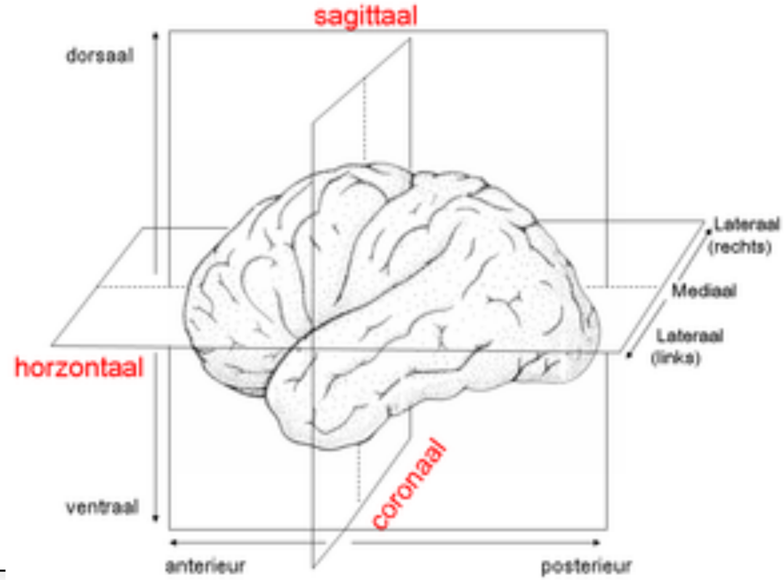
Dolphin brain 40% adult size at birth – vs. Human ~ 25% adult size at birth

Brain Development

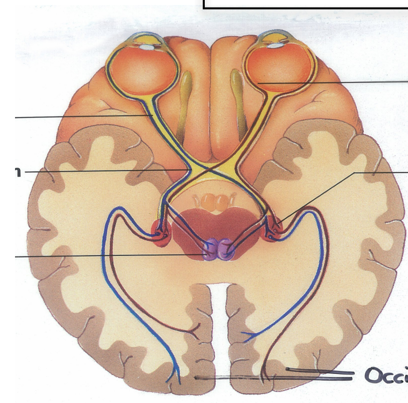
Due to similar impedance of seawater & amniotic fluid, developing fetus receives much auditory input.

e.g. Mother repeats her signature whistle near end of pregnancy, so infant is born already able to recognize it.

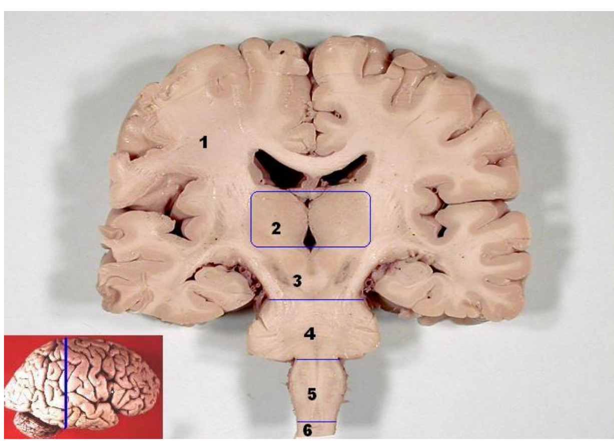
On sectioning the brain...



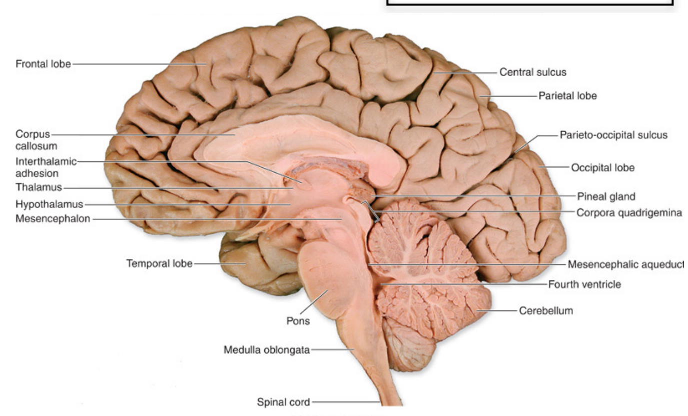
Horizontal Section



Coronal Section



Saggital Section



Auditory Pathway

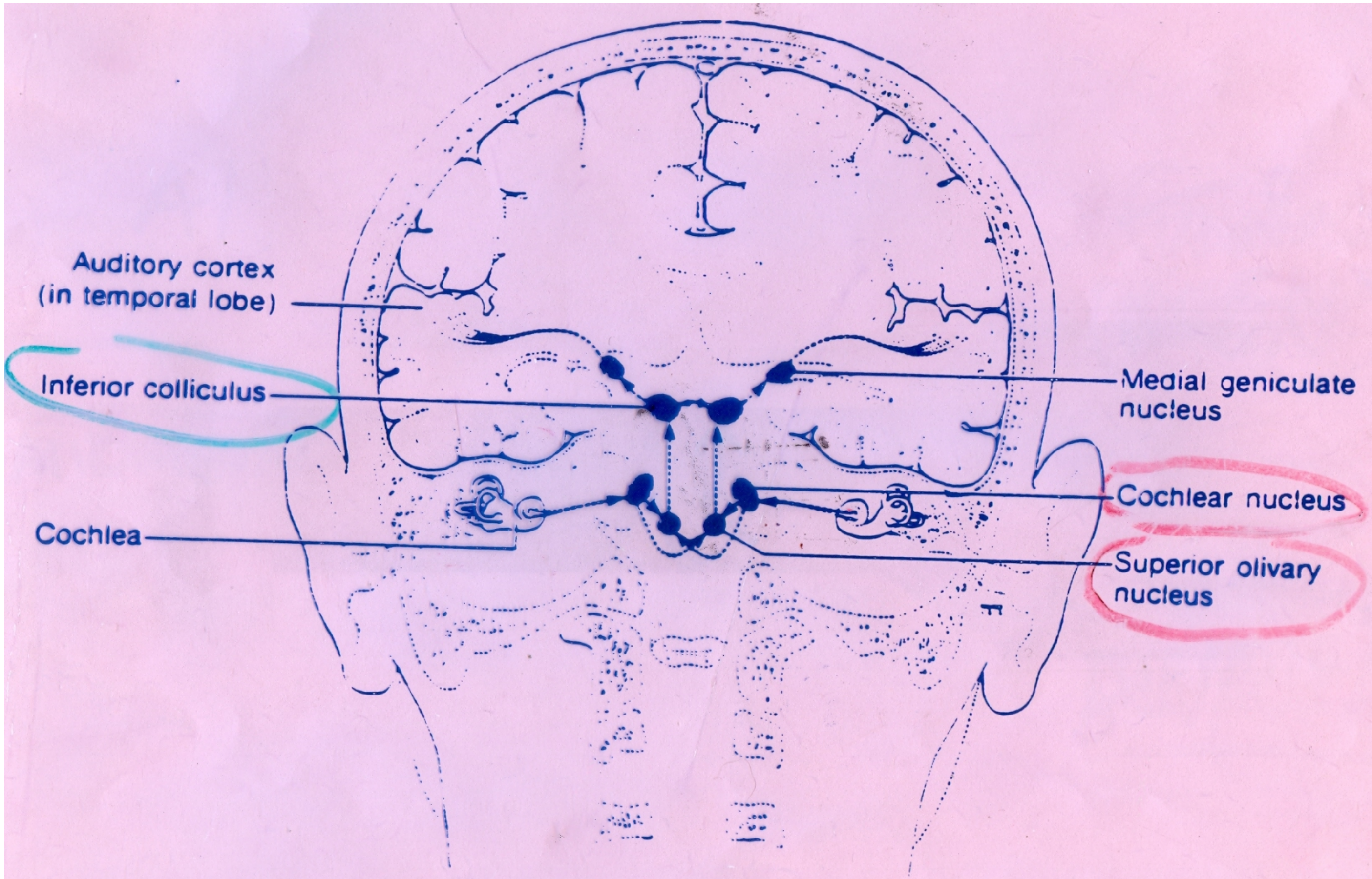


FIGURE 12. 12 Simplified diagram of the auditory pathways. (Adapted from Wever, 1949.)

Auditory Brain Stem

Bottlenose dolphin

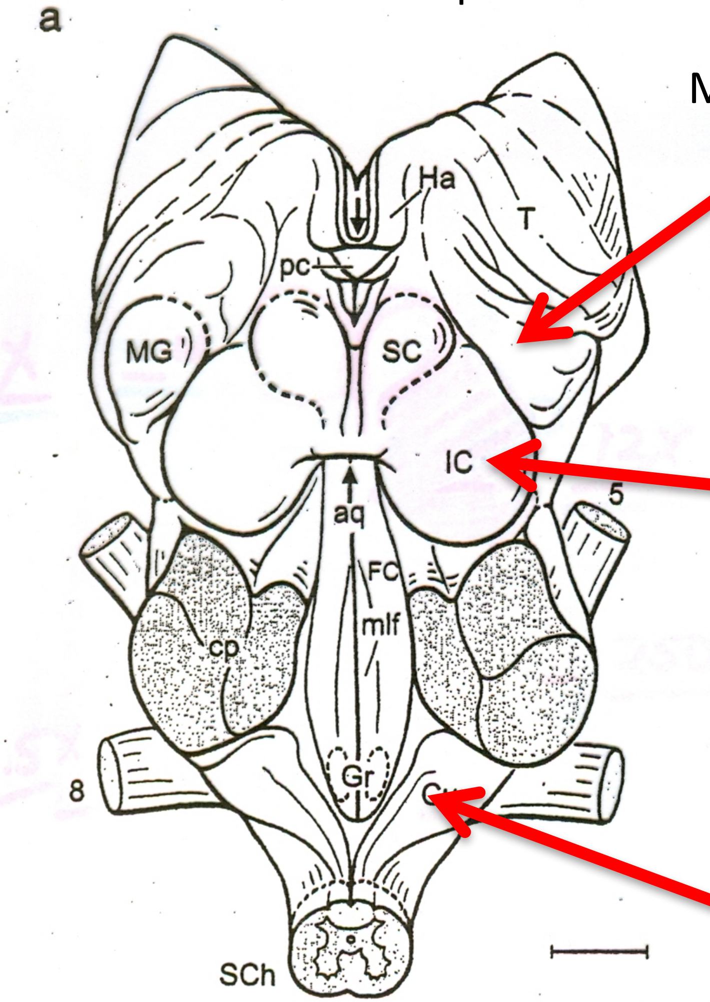


Figure 8 *Brain stem of the bottlenose dolphin*

MGN of Thalamus 7X

Inferior Colliculus 12X

Lateral Lemniscus (Medulla) 250X

Human

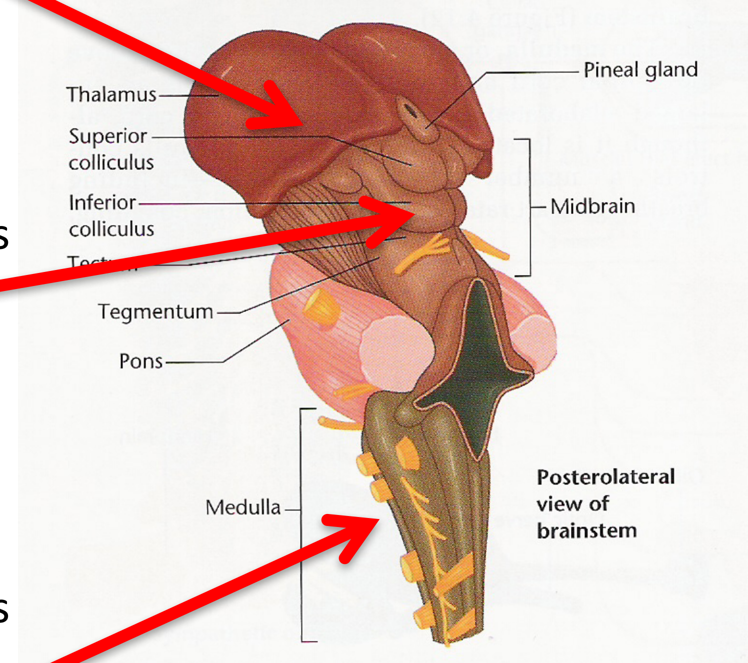
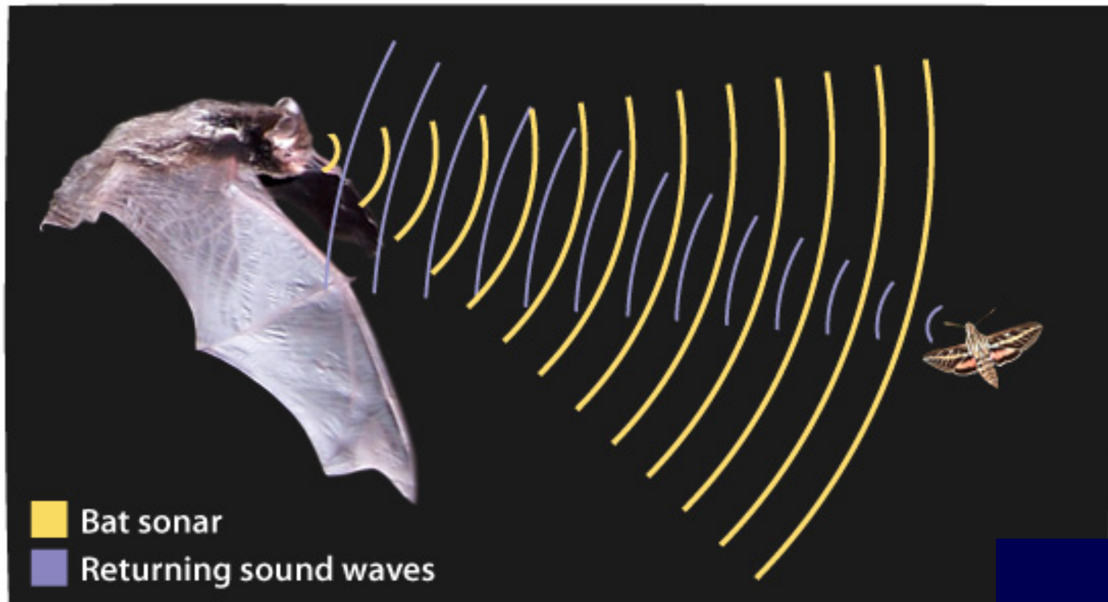
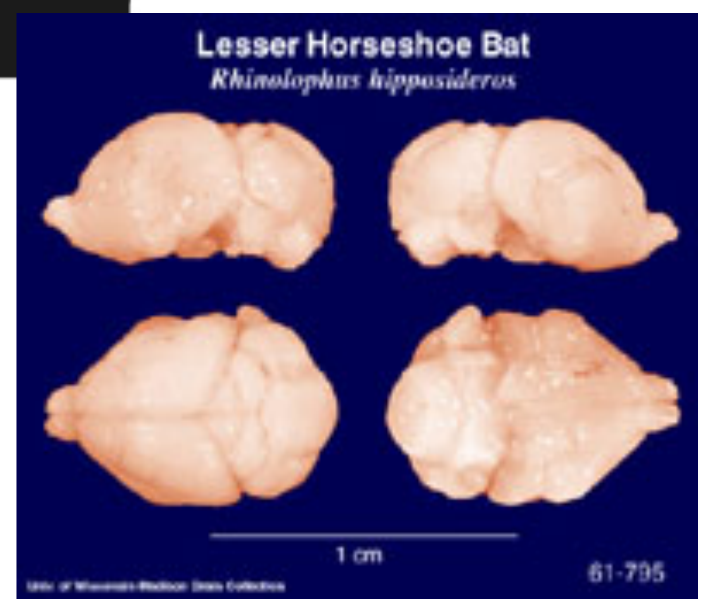


Figure 4.12 The human brainstem

Bats also good echolocators – little brain





Dolphin Audition – Dual Processing System

Brainstem for ultra-sonic, ultra-brief, rapidly-changing = Echolocation

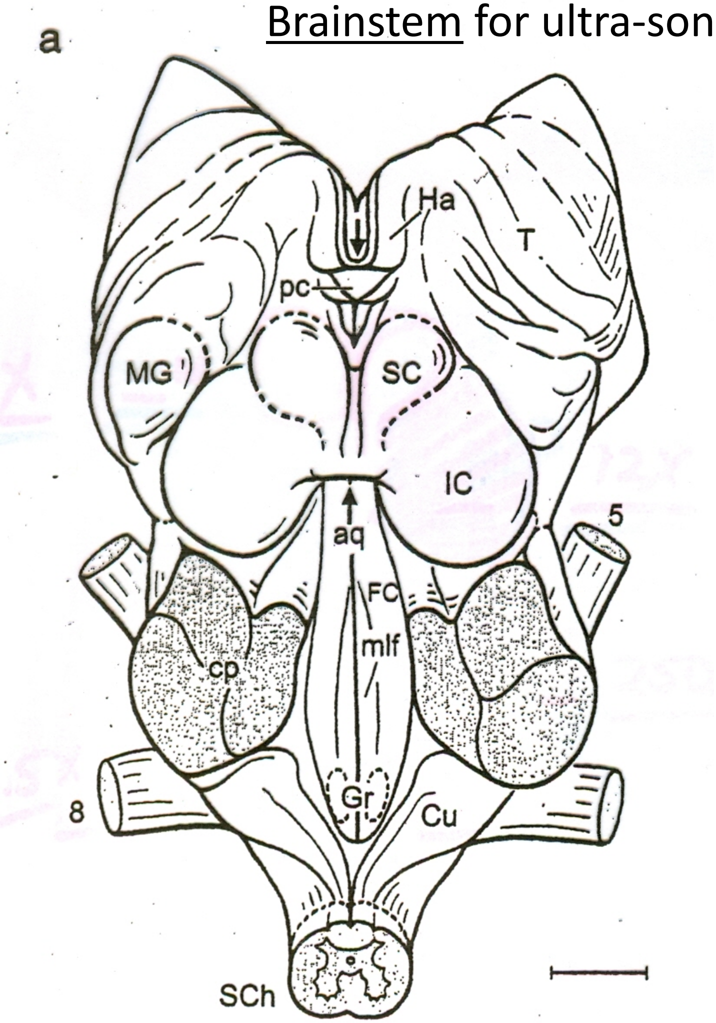


Figure 8 *Brain stem of the bottlenose dolphin*

Dolphin Audition – Dual Processing System

Brainstem for ultra-sonic, ultra-brief, rapidly-changing = Echolocation

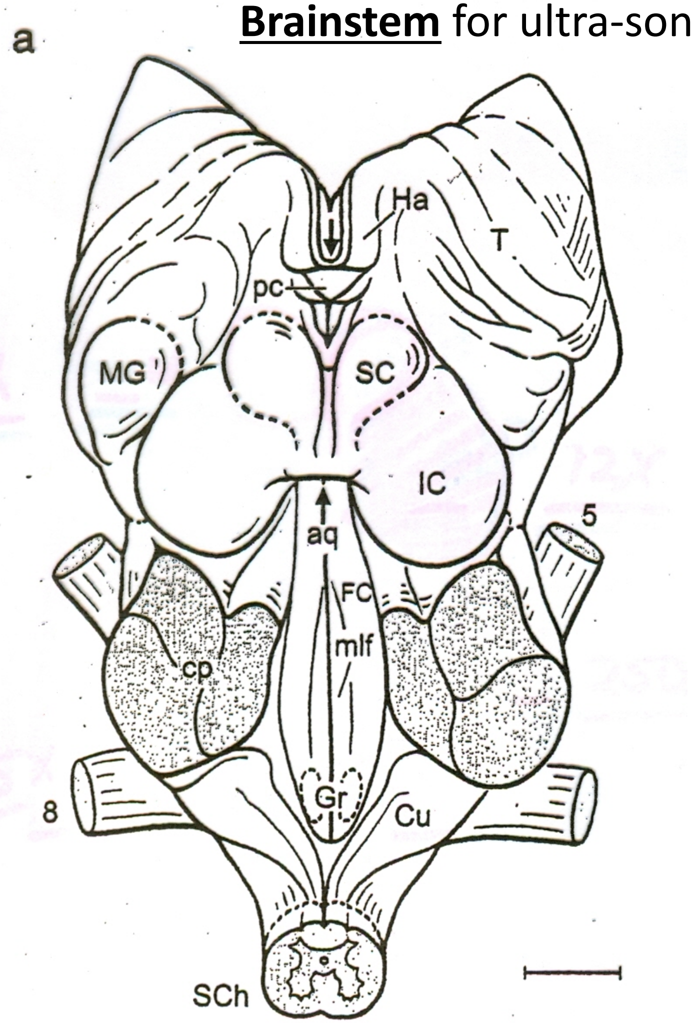
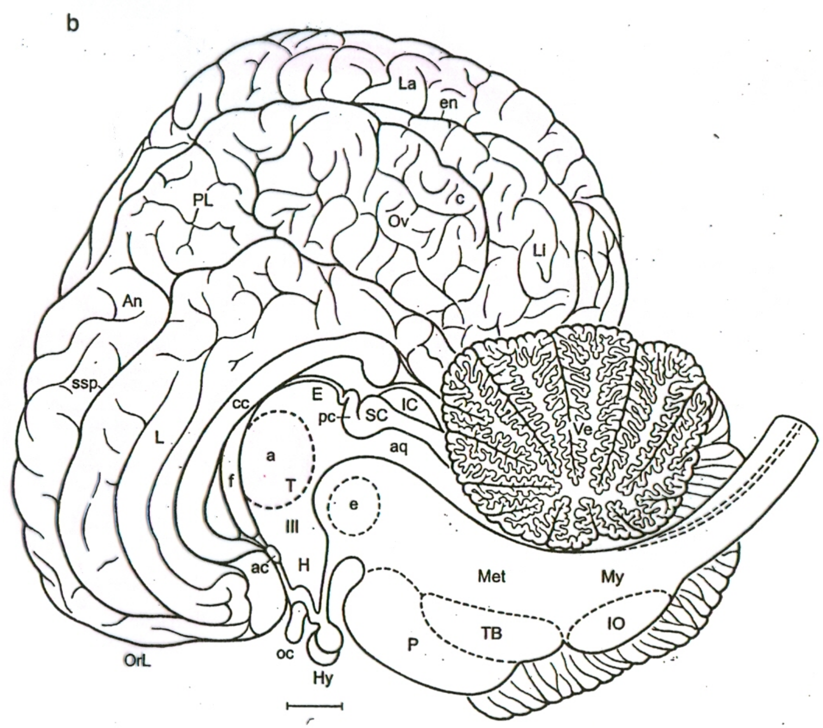
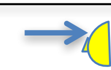


Figure 8 *Brain stem of the bottlenose dolphin*

Auditory Cortex –
For "**higher**" auditory processing





Vision

No fovea, One cone type (no color), Rods (for motion) predominant
Optic nerve ~140,000 fibers (vs. human 1.6 million)

Vision

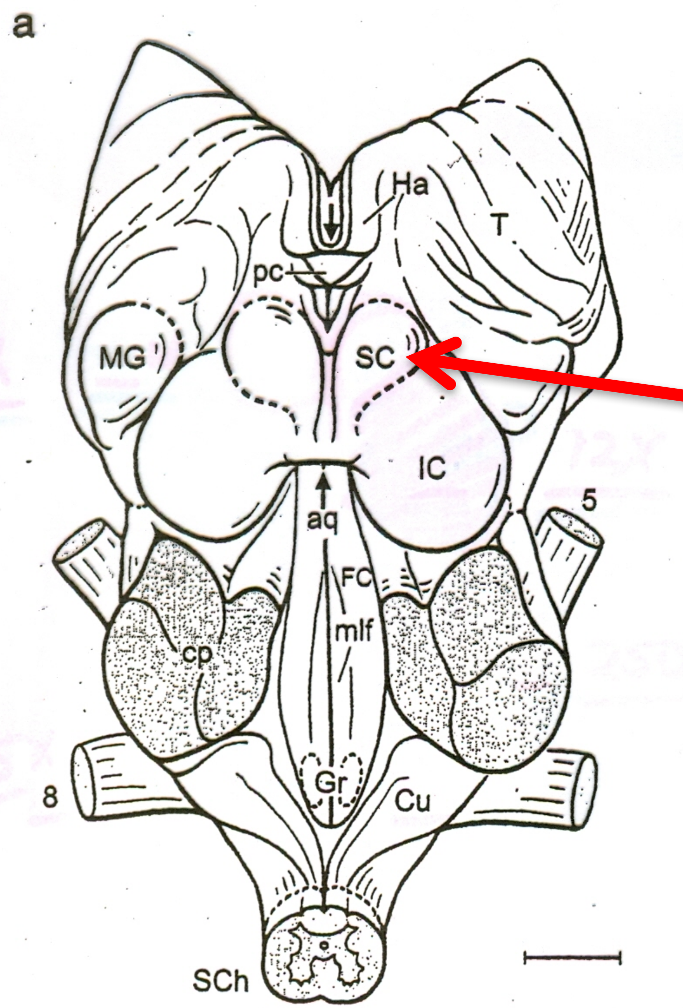


Figure 8 *Brain stem of the bottlenose dolphin*

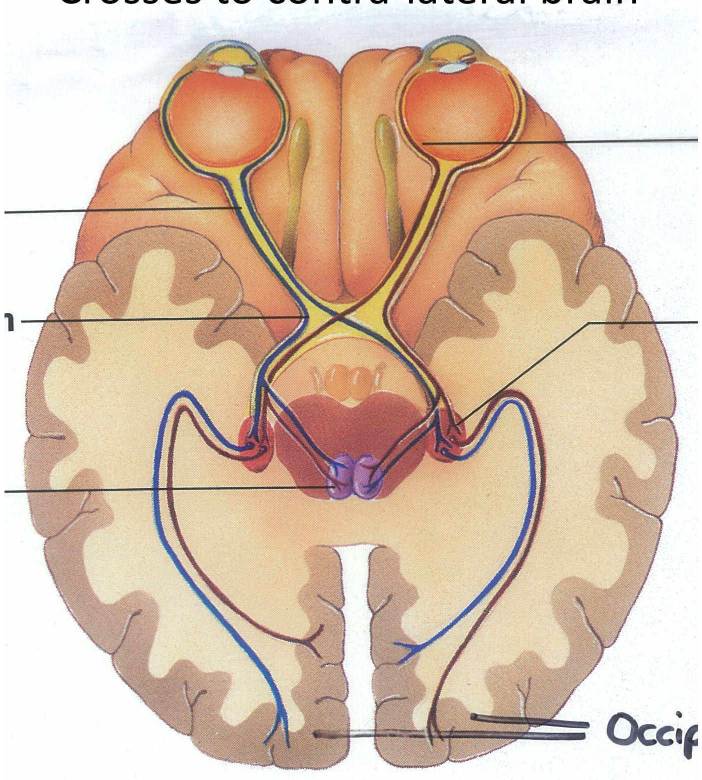
While (auditory) Inferior Colliculus is larger, dolphin midbrain also has well-developed Superior Colliculus

Superior colliculus larger than HUMANS (despite our primacy of vision)

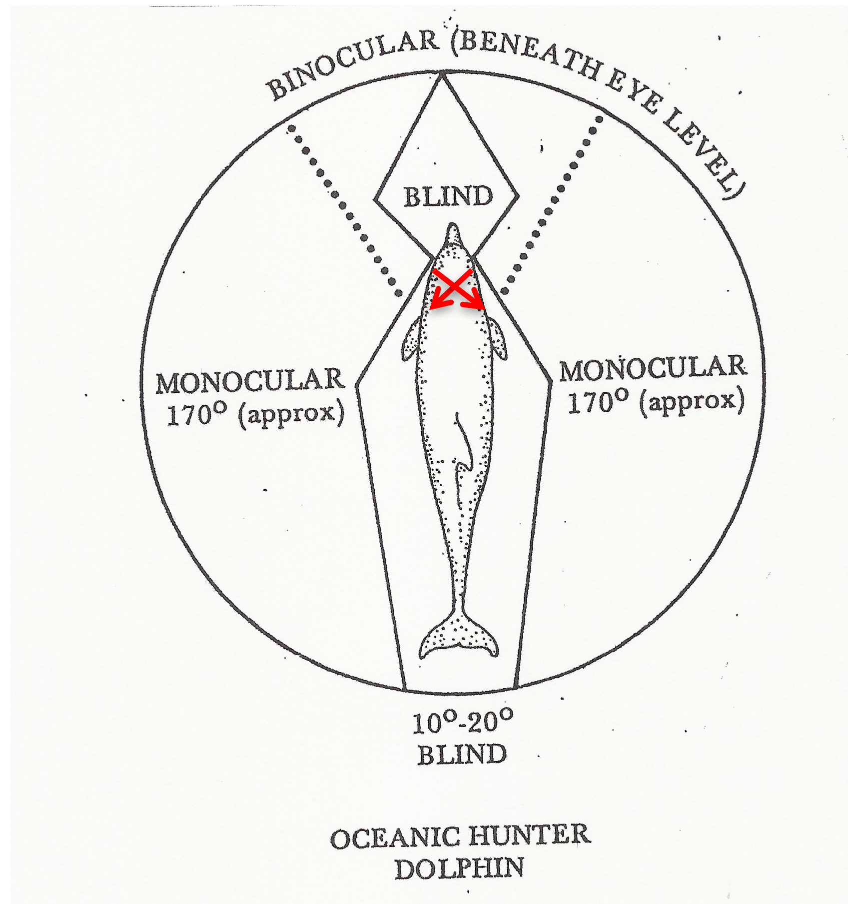
Superior colliculus for **VISUAL MOTION**

Vision

Primates:
Half visual field to half of both eyes,
Crosses to contra-lateral brain



Cetaceans:
Each half visual field to ONE eye,
Crosses to contra-lateral brain

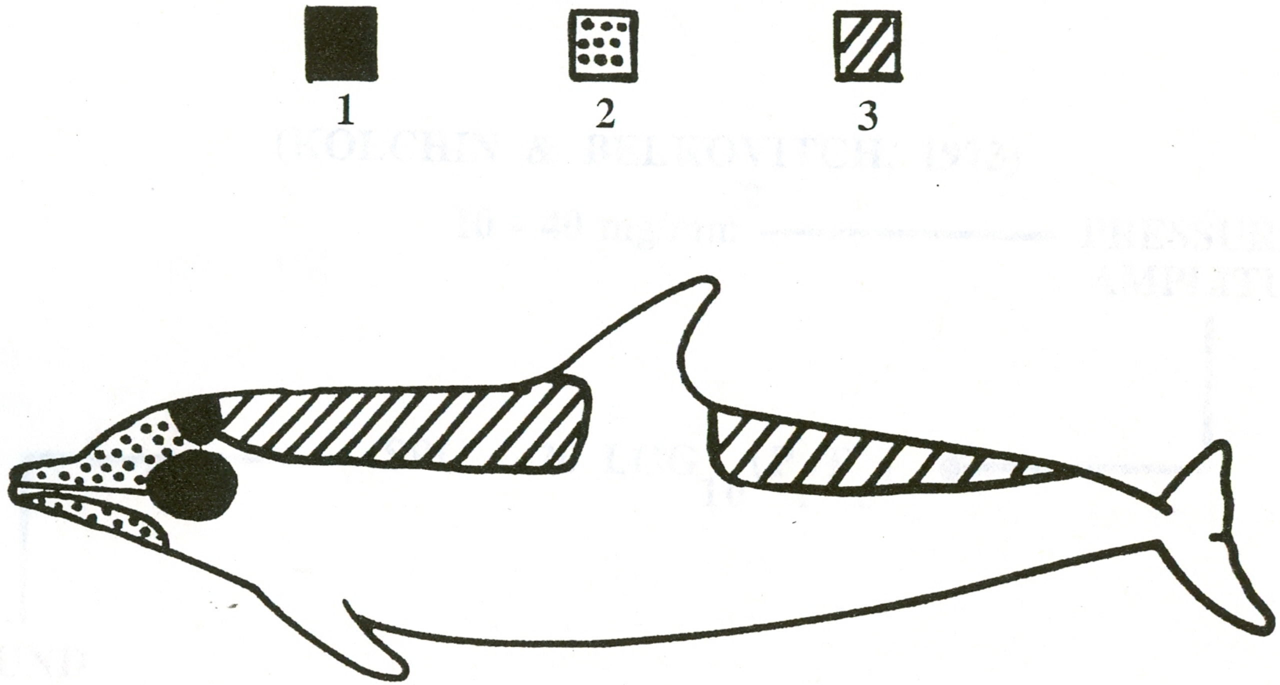


Vision

DO examine with both eyes…

Somatosensory

SKIN SENSITIVITY MAP

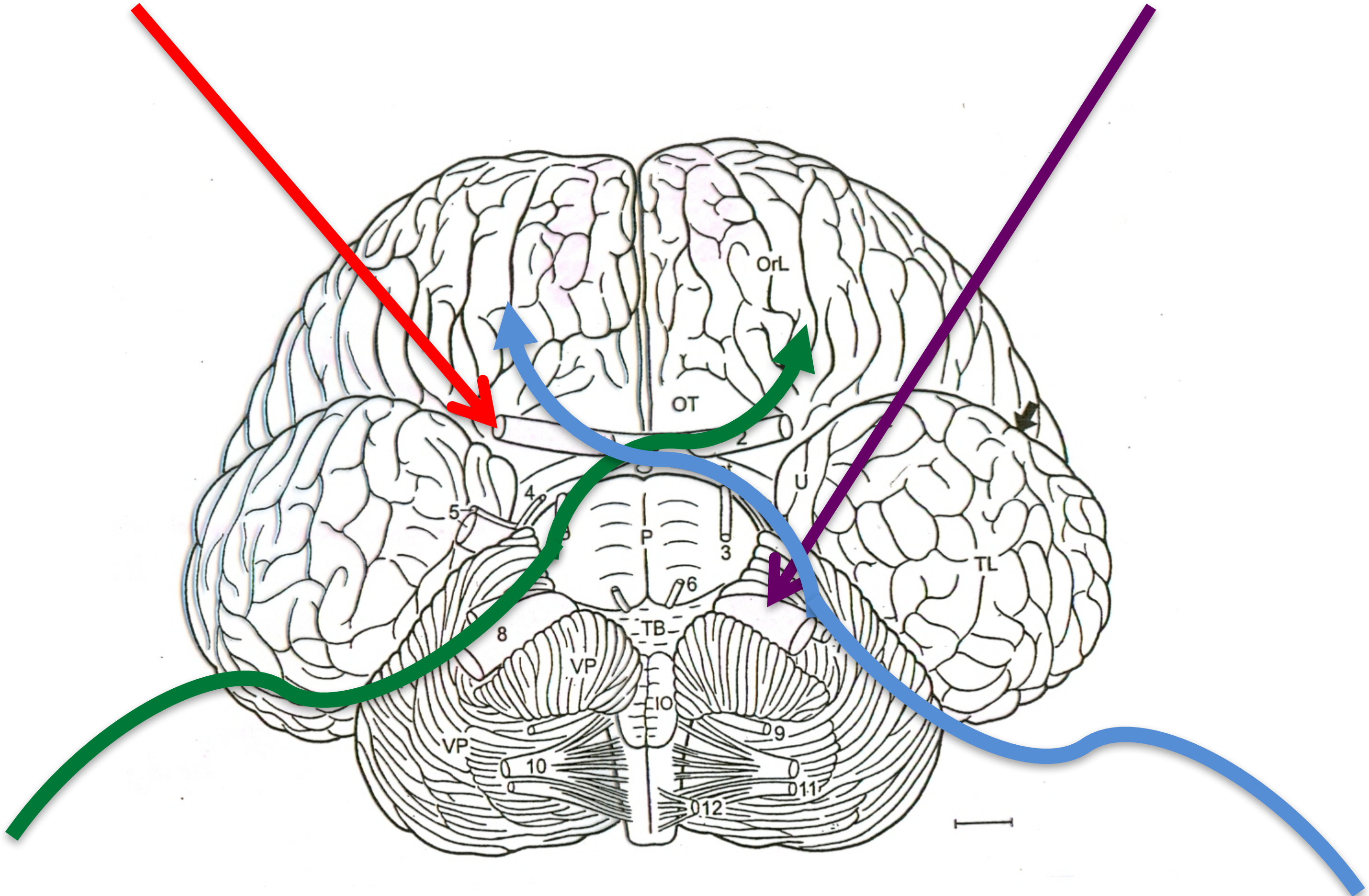


1 = 10 mg/mm^2 2 = 10 - 20 mg/mm^2 3 = 20 - 40 mg/mm^2

SOURCE: KOLCHIN & BELKOVICH, 1973

Somatosensory

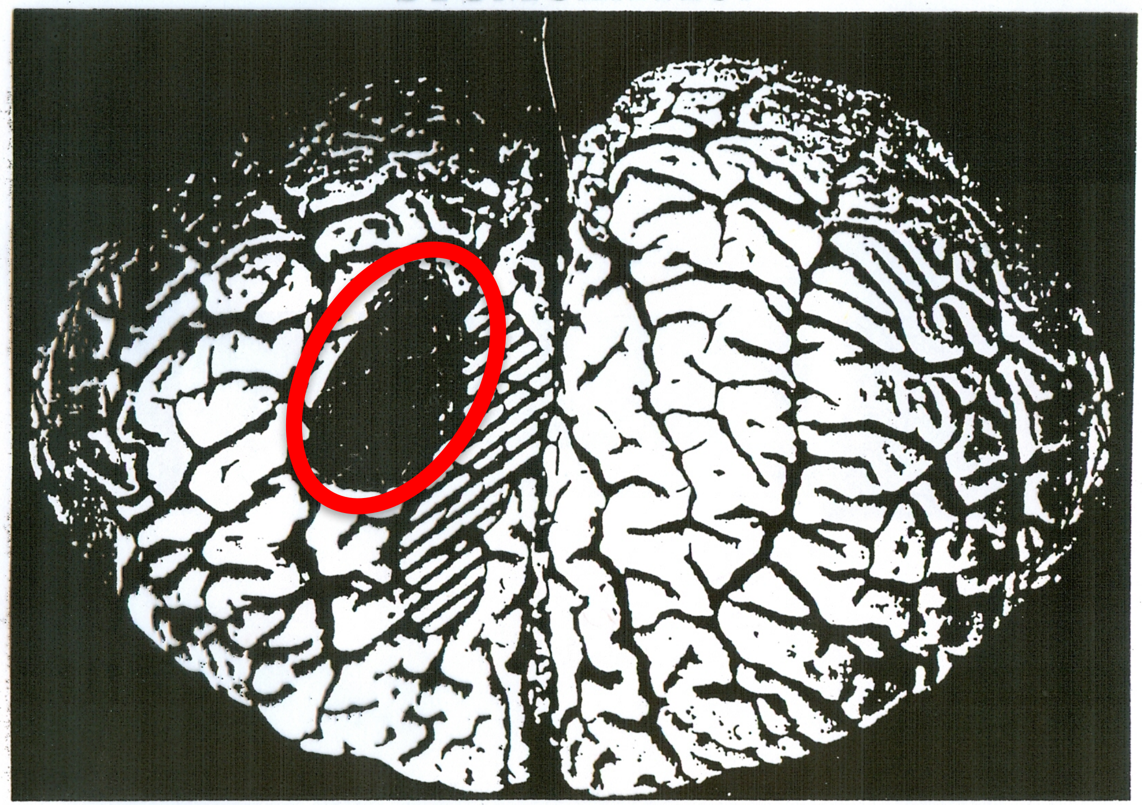
Trigeminal nerve (Somatosensory for face) – Second only to **Auditory**



Somatosensory **pathways** are contra-lateral

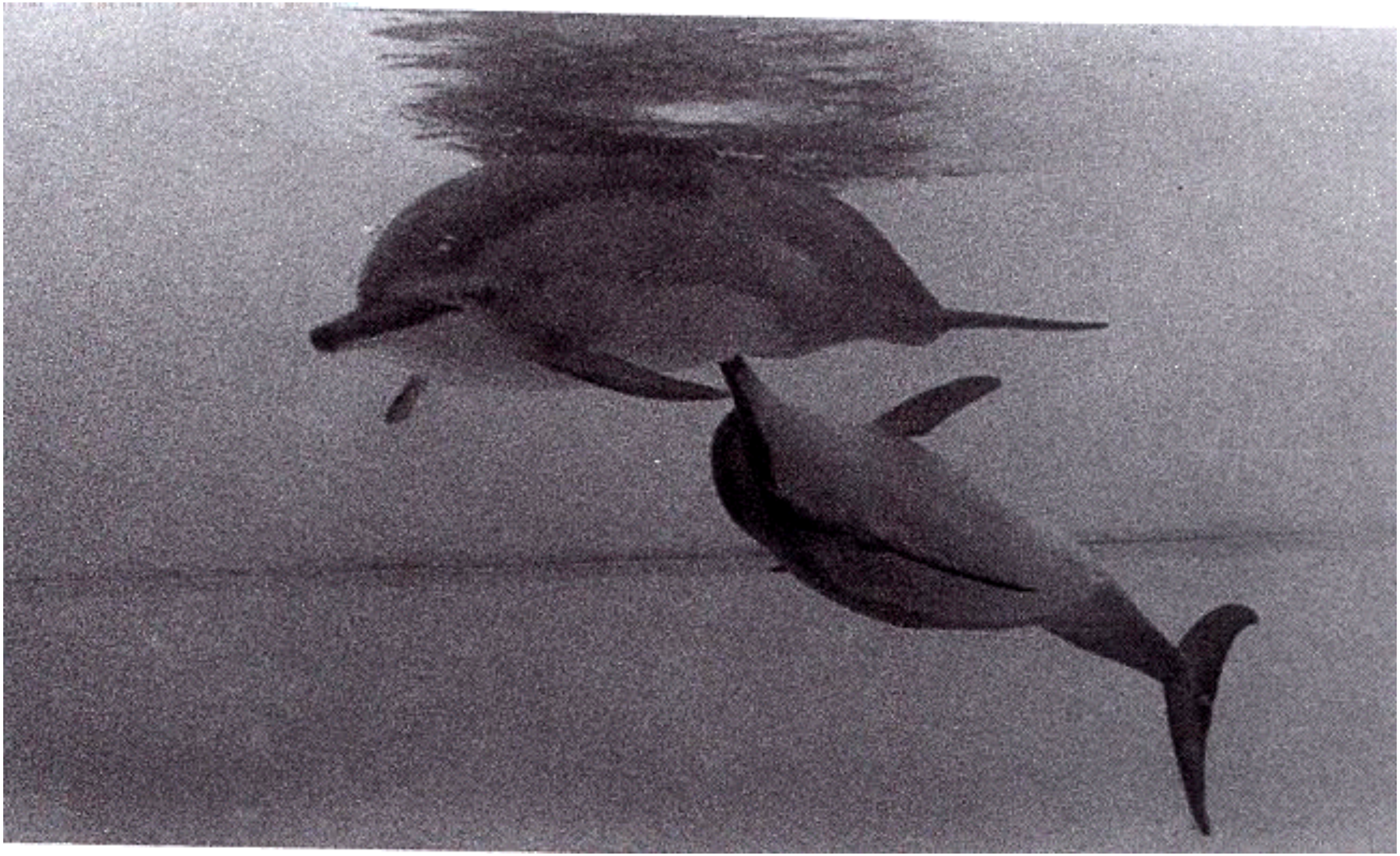
Tacto-Acoustic

UNUSUAL SENSORY CORTEX in <u>TURSIOPS</u> <u>TRUNCATUS</u> WHICH RESPONDS TO BOTH TACTILE and ACOUSTIC STUMULATION



SOURCE: LENDE & WELKER, 1972

Tacto-Acoustic



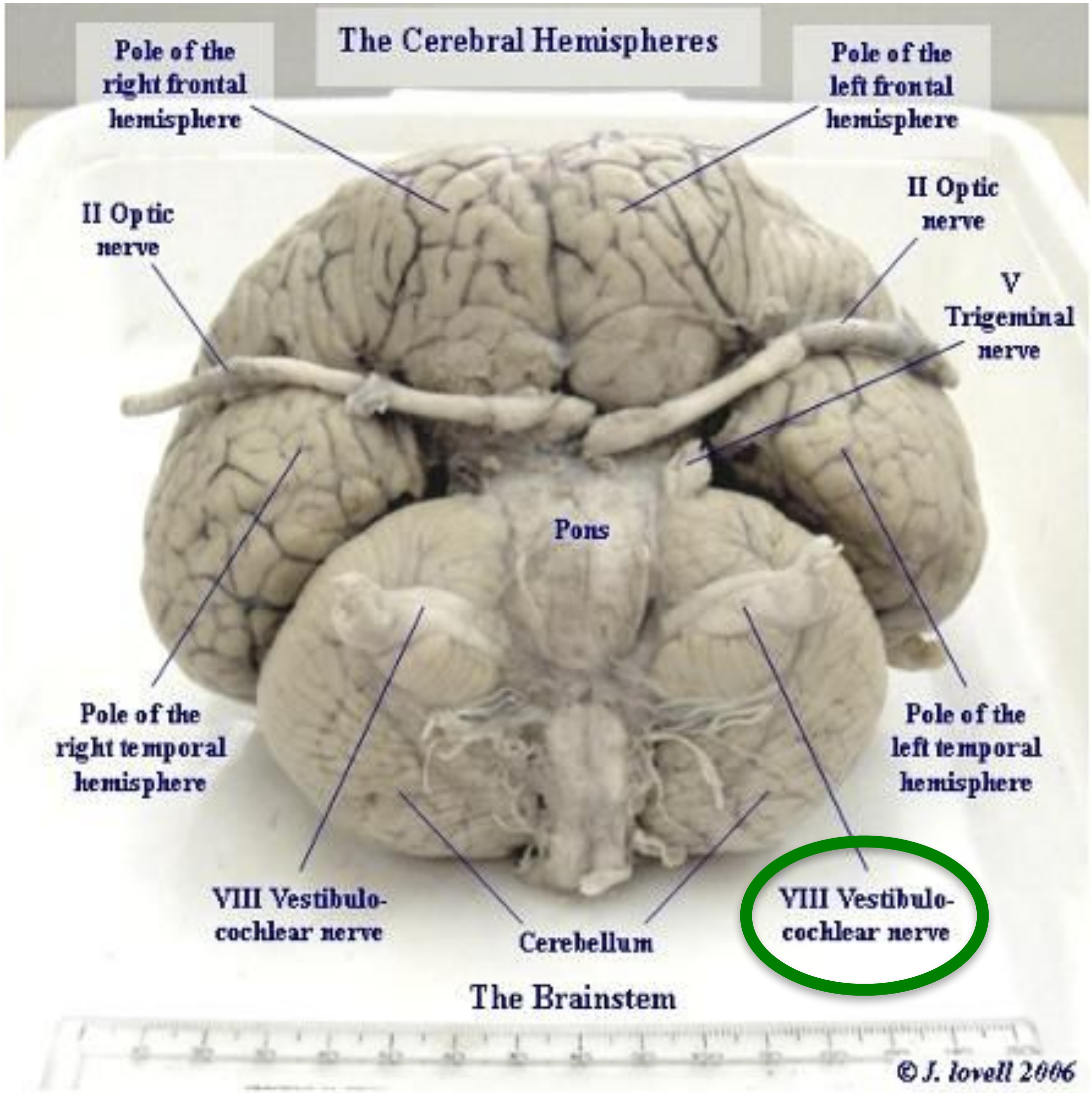
Vestibular

Tracts **much reduced** (only ~1/3) compared to other mammals

???

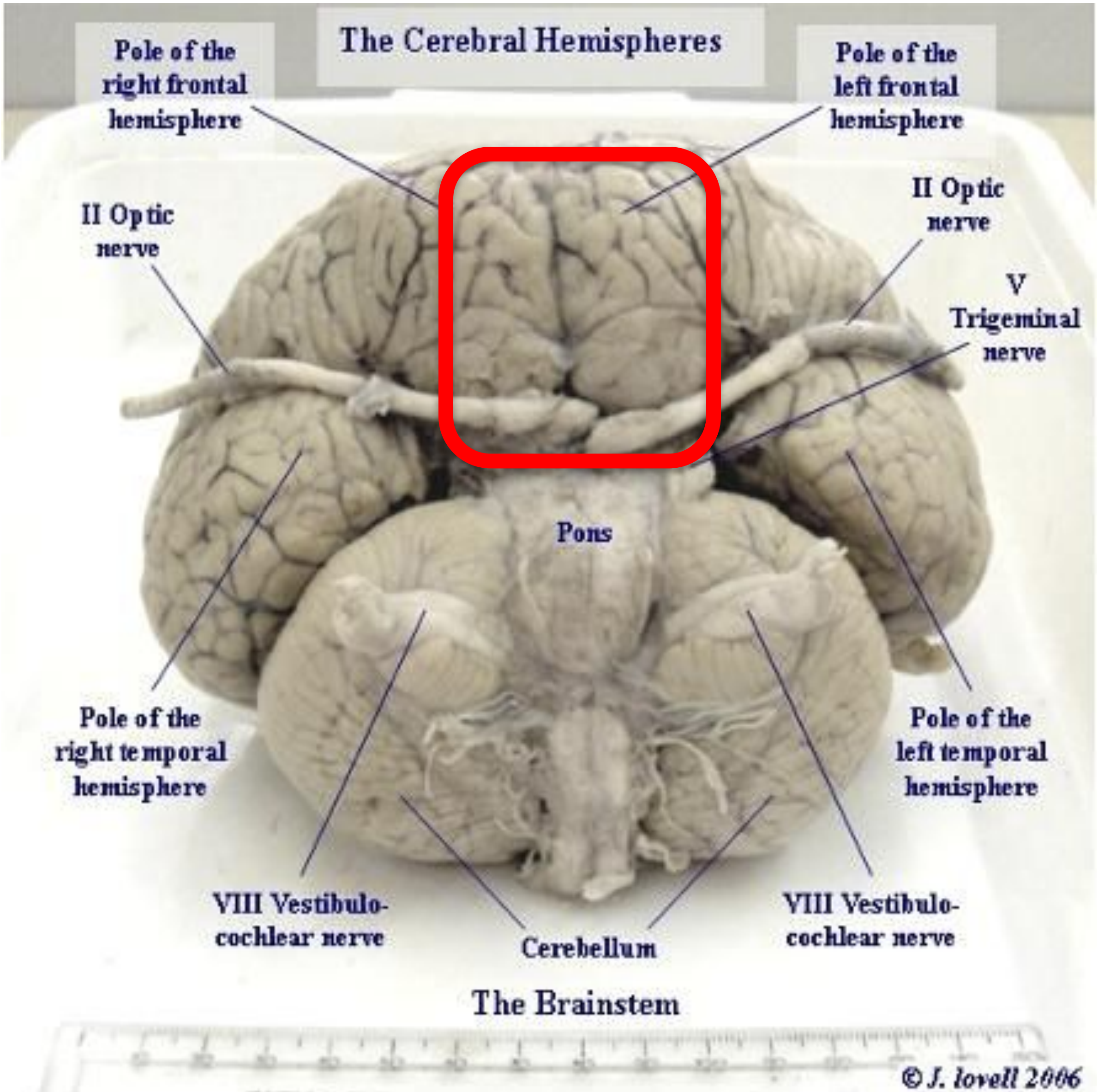
Graceful, agile

Neutrally buoyant
so can't use gravity
to detect change in tilt

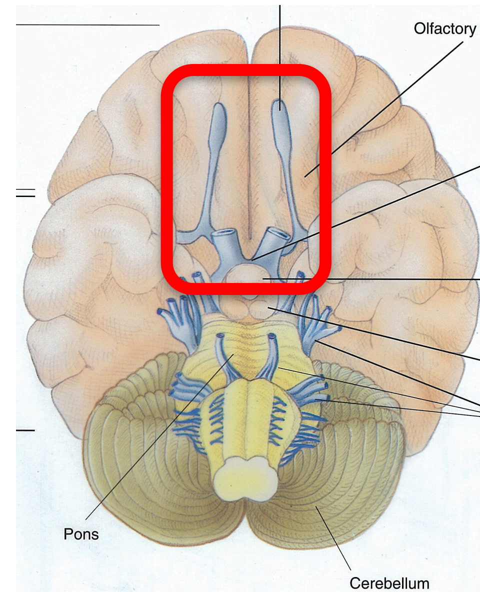


Limbic System

NO olfactory bulbs (No smell, although do taste)



Human



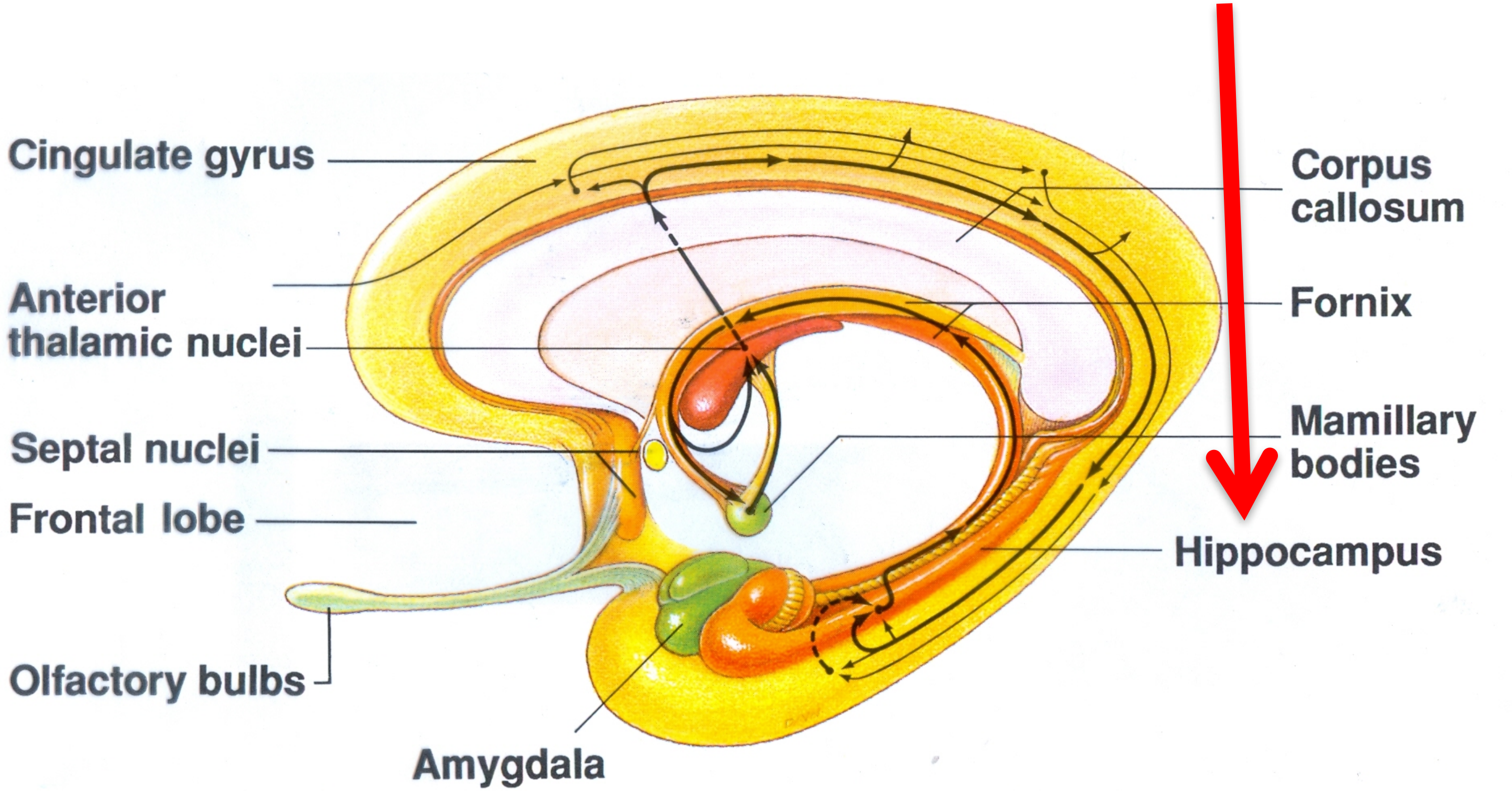
So, Limbic System not = "Rhinecephalon"

Limbic System

Hippocampus **reduced**

But excellent memory . . .

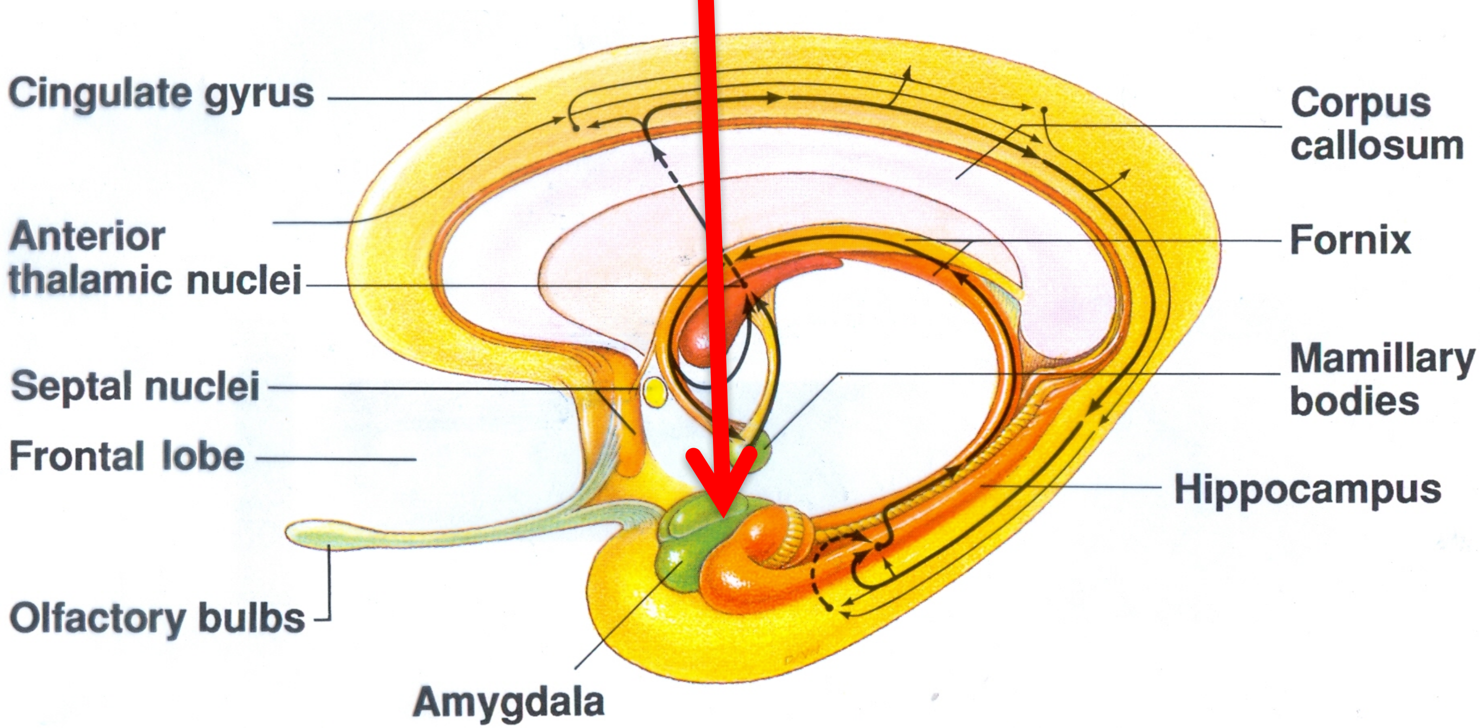
?? Reduced spatial mapping??



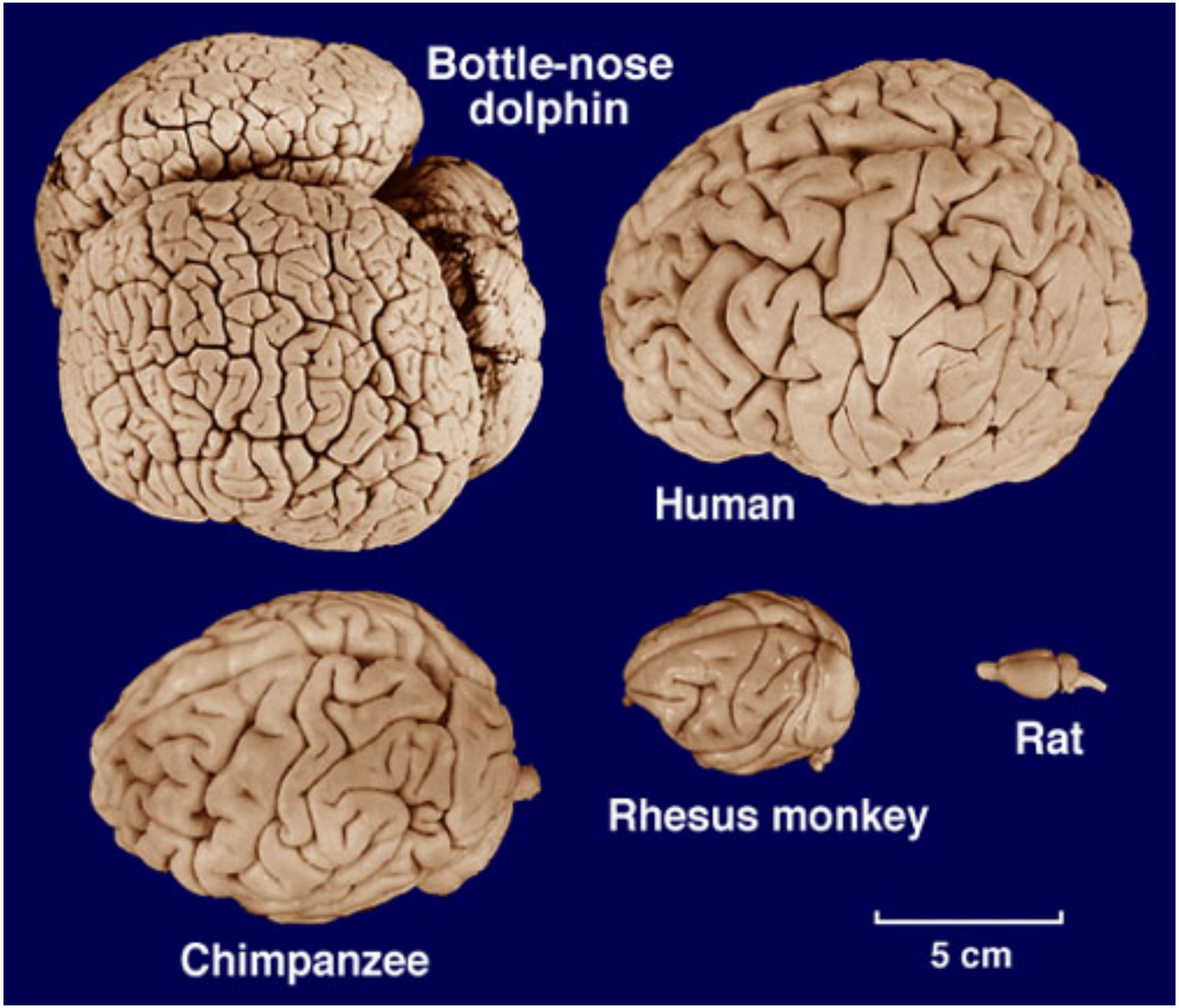
Limbic System

Amygdala **enlarged**

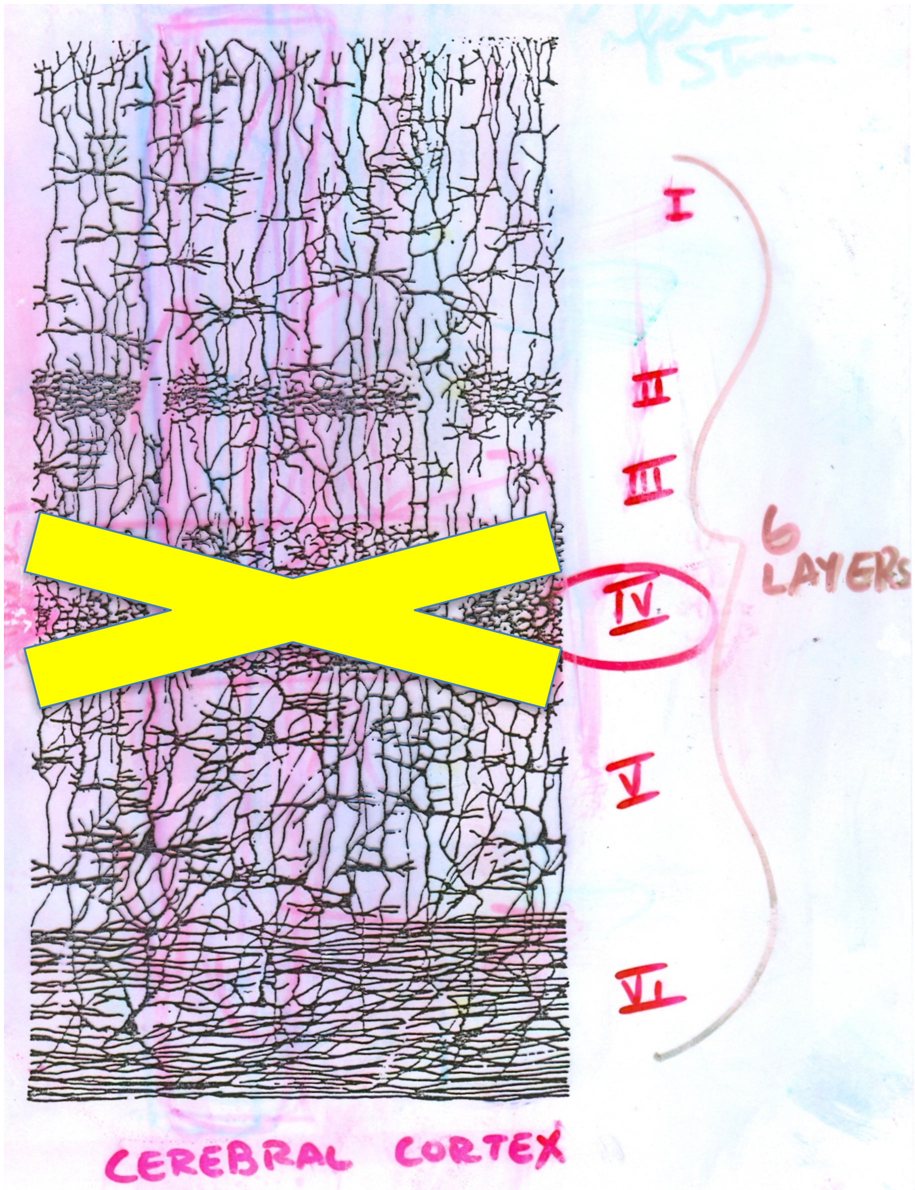
Emotional expression/interpretation
Esp well connected w/Auditory system
? Theory-of-mind ?



Cerebral Cortex



Cerebral Cortex

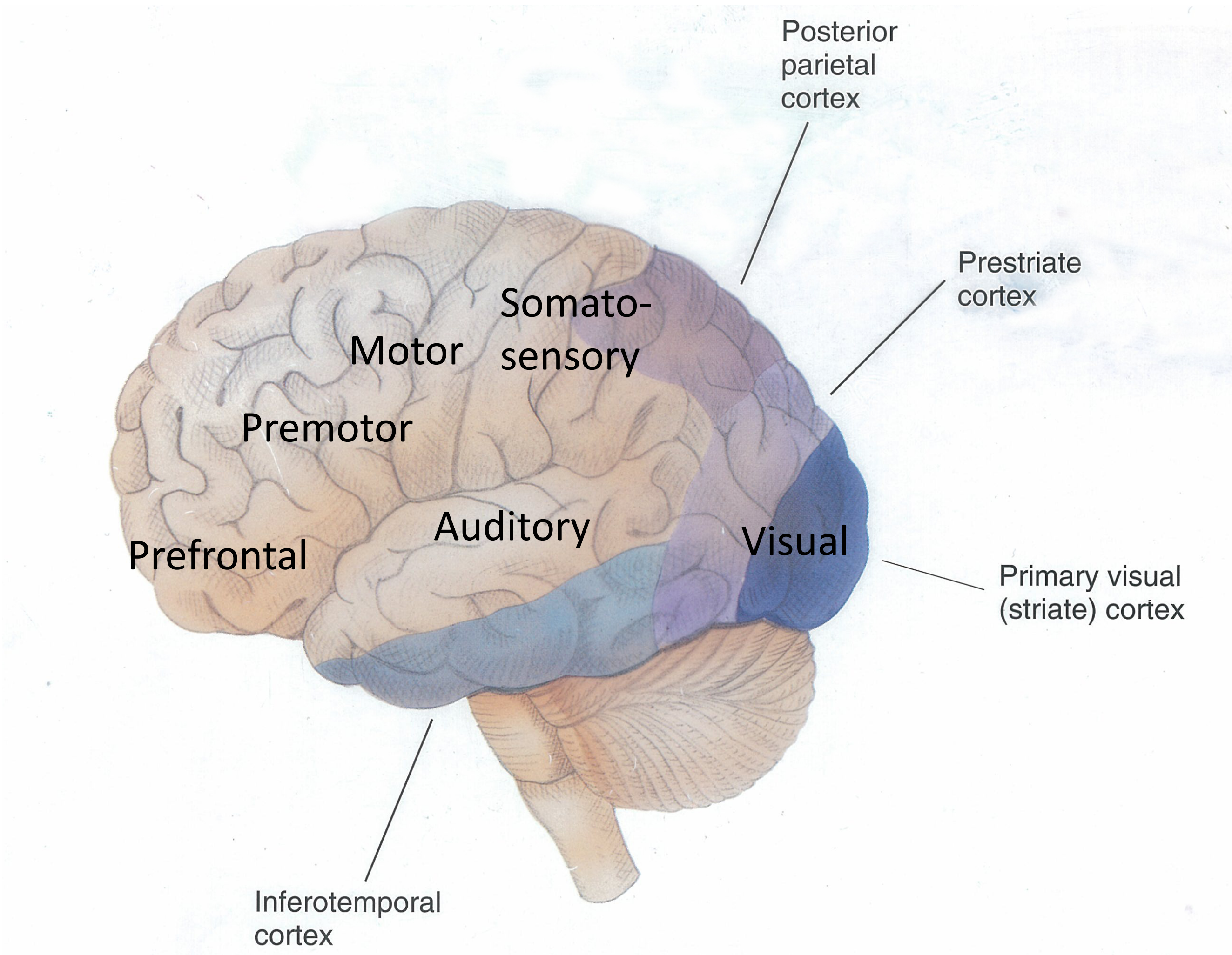


Cytoarchitecture:
Dolphin cortex has NO granular Layer 4!!

NOTE: DO see Layer 4 In fetal brain, so loss is a **secondary adaptation**…

Cerebral Cortex

Unlike with Brain Stem, more difficult to map homologues to other mammalian cortex



Cerebral Cortex

Unlike with Brain Stem, more difficult to map homologues to other mammalian cortex

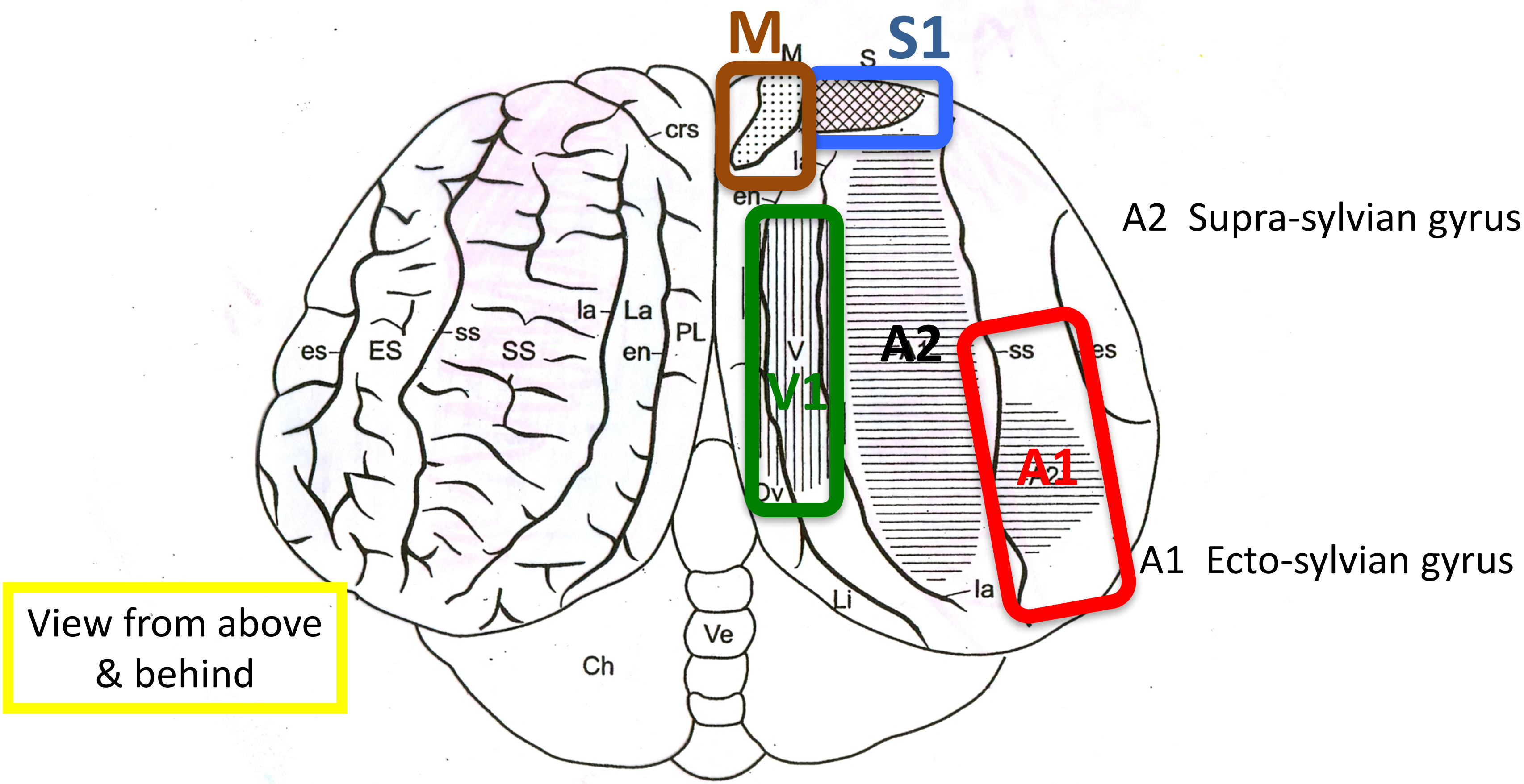
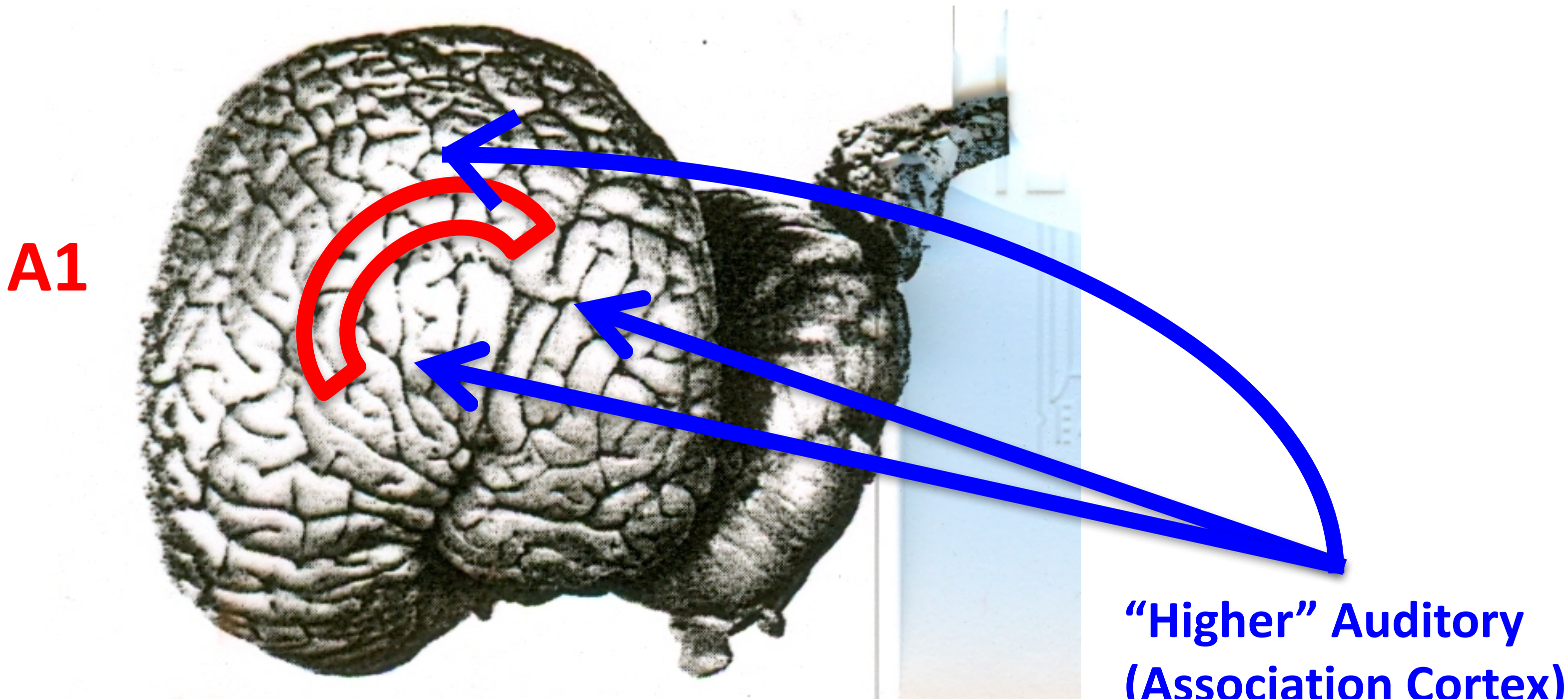


Figure 12 *Neocortical motor and sensory fields in the bottlenose dolphin. A1, A2, auditory fields; crs, cruciate sulcus; M, motor field; PL, paralimbic lobe; S, somatosensory field; V, visual field. After Morgane* et al. *(1986).*

Cerebral Cortex

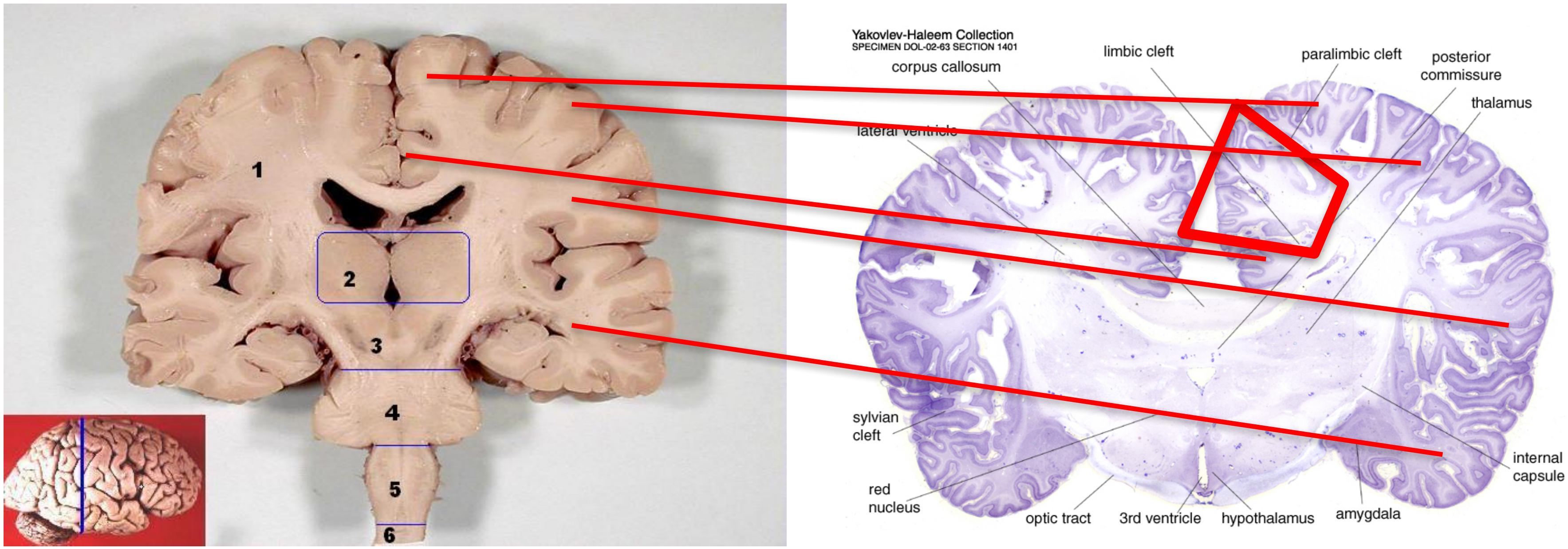
Unlike with Brain Stem, more difficult to map homologues to other mammalian cortex



Lateral view of brain of the bottlenose

The Cortex

Extra Paralimbic Lobe



Human

Coronal Section

Dolphin

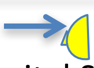
Coronal Section

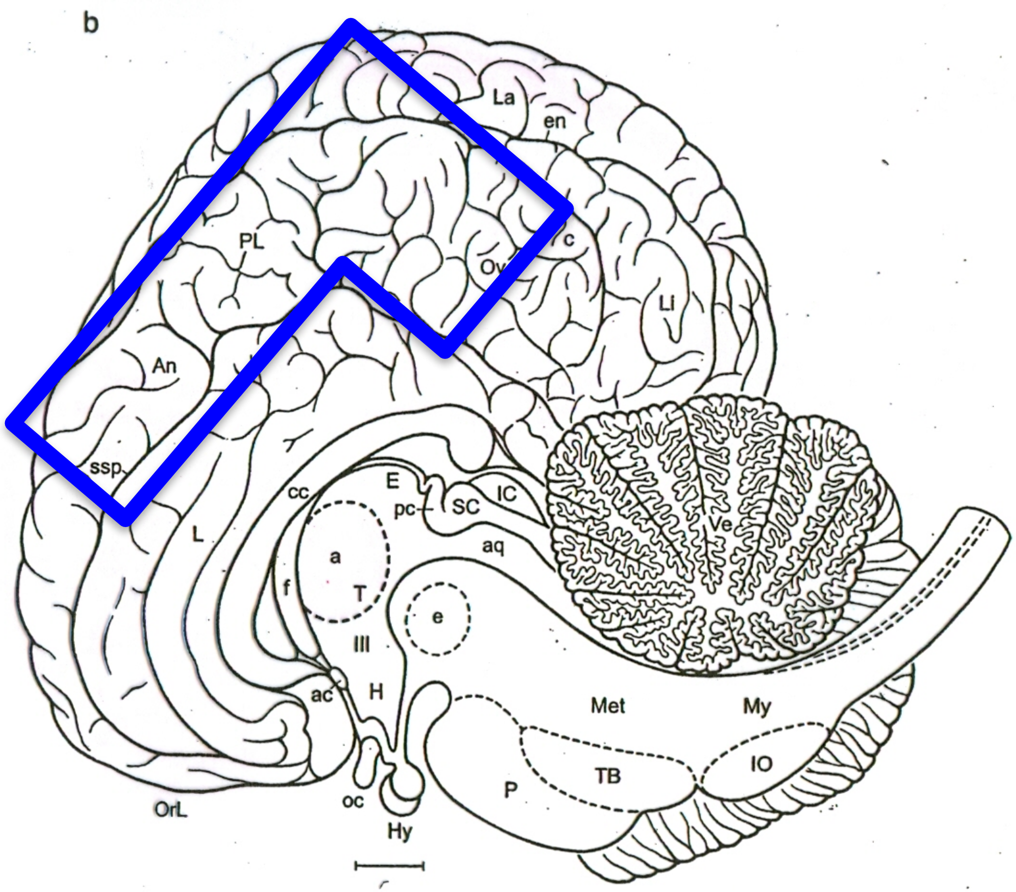
Cerebral Cortex

Paralimbic Cortex

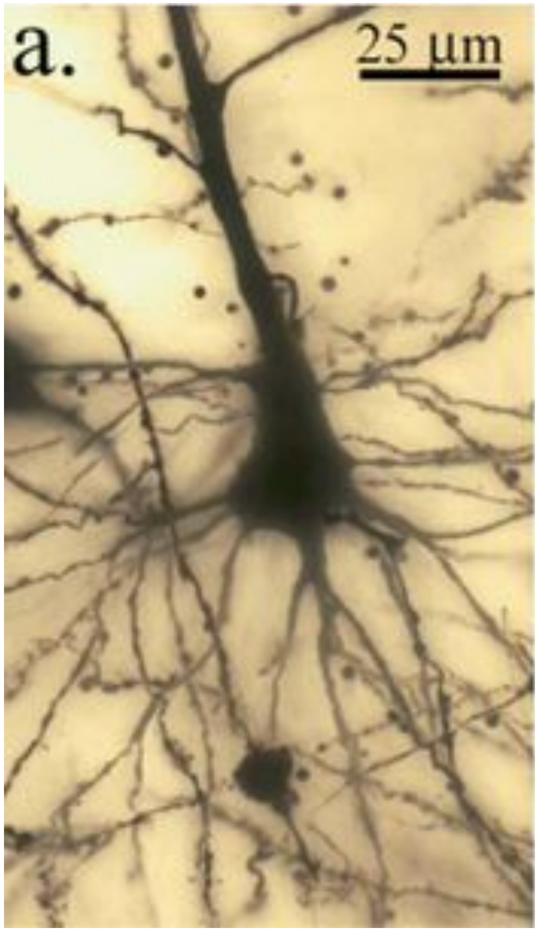
Some characteristics similar to
Higher Visual Cortex
in humans

Function??
Like Primate Orbito-Frontal???

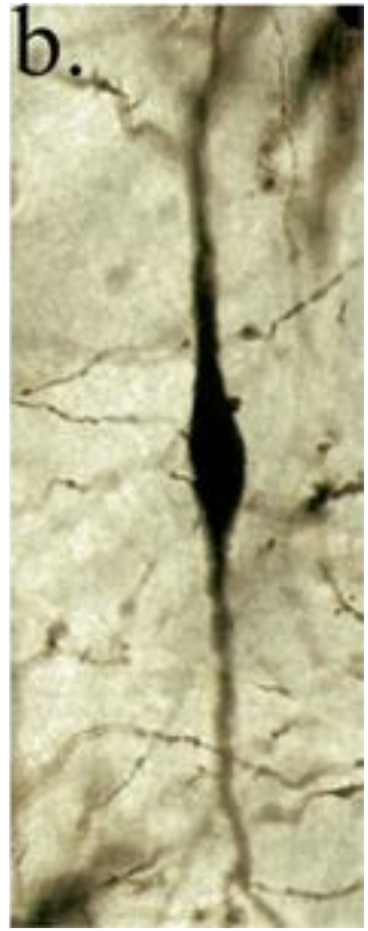




Von Economo Cells



Typical Pyramidal Cell



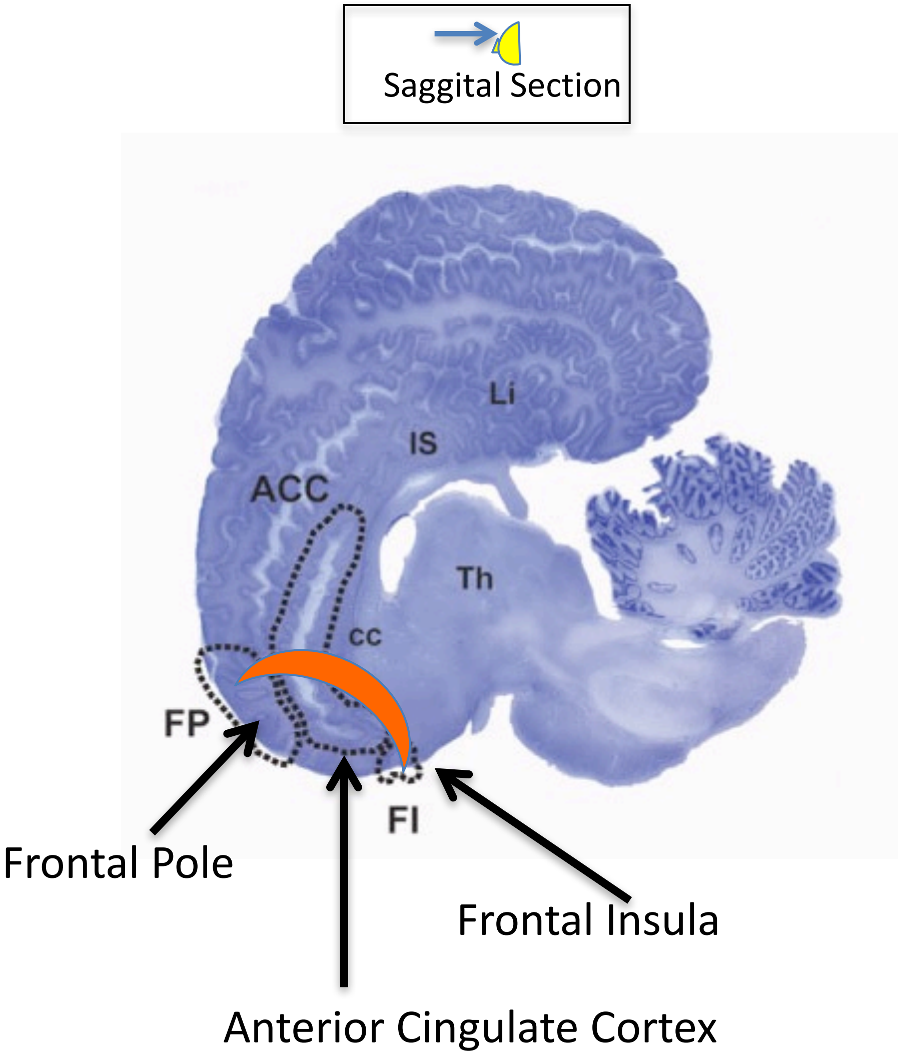
Von Economo
or “Spindle” Cell

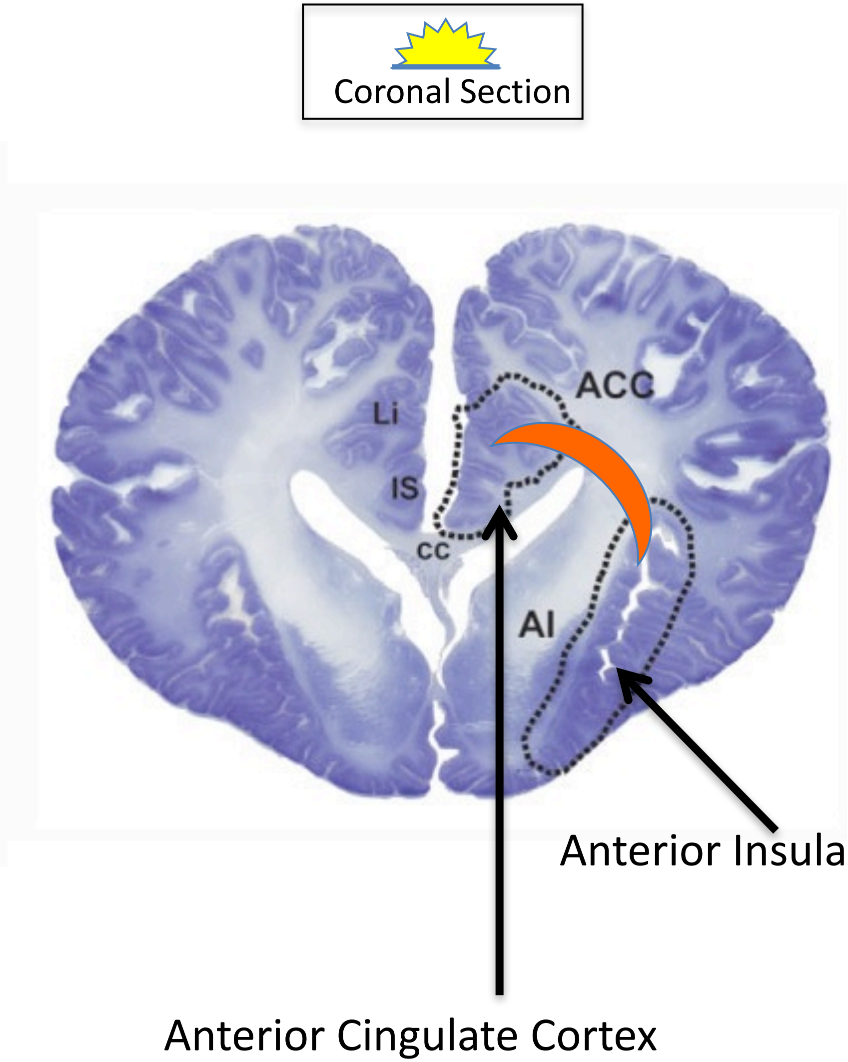
For “long distance”
Communication in large brains

Found in Humans & Apes
(not monkeys)

Found in several Cetaceans
e.g. Humpback [a Mysticete],
Sperm Whale,
Bottlenose Dolphin & Beluga

Von Economo Cells

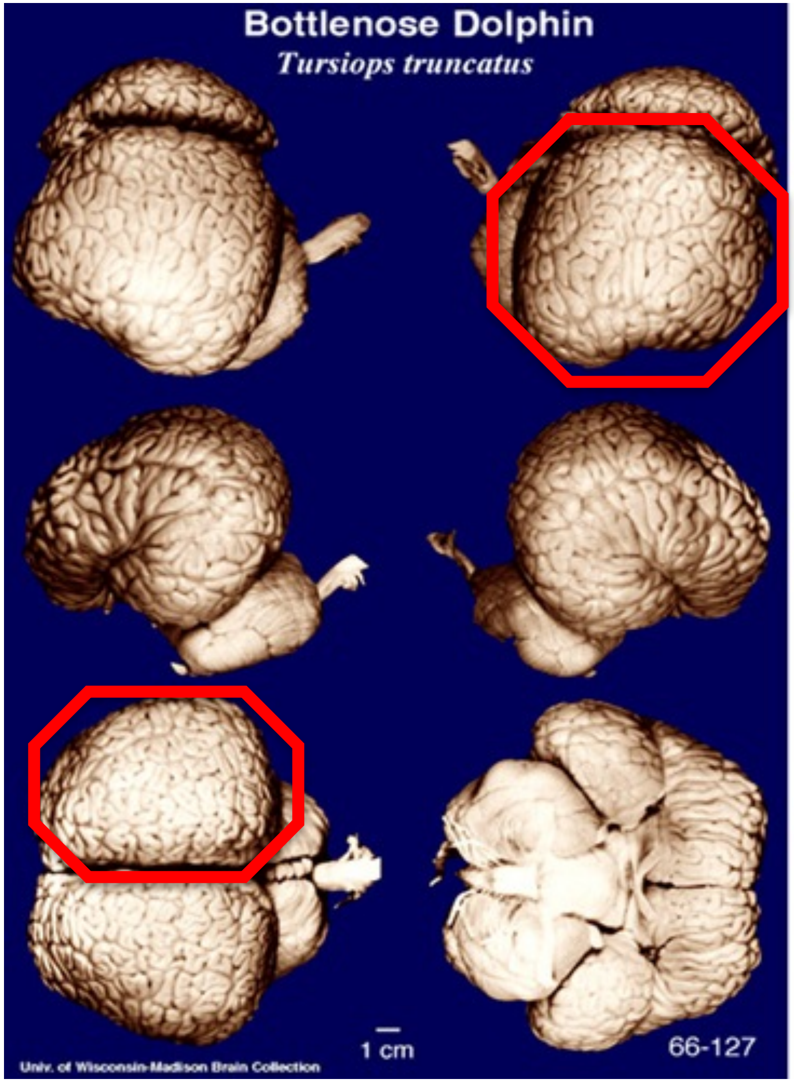


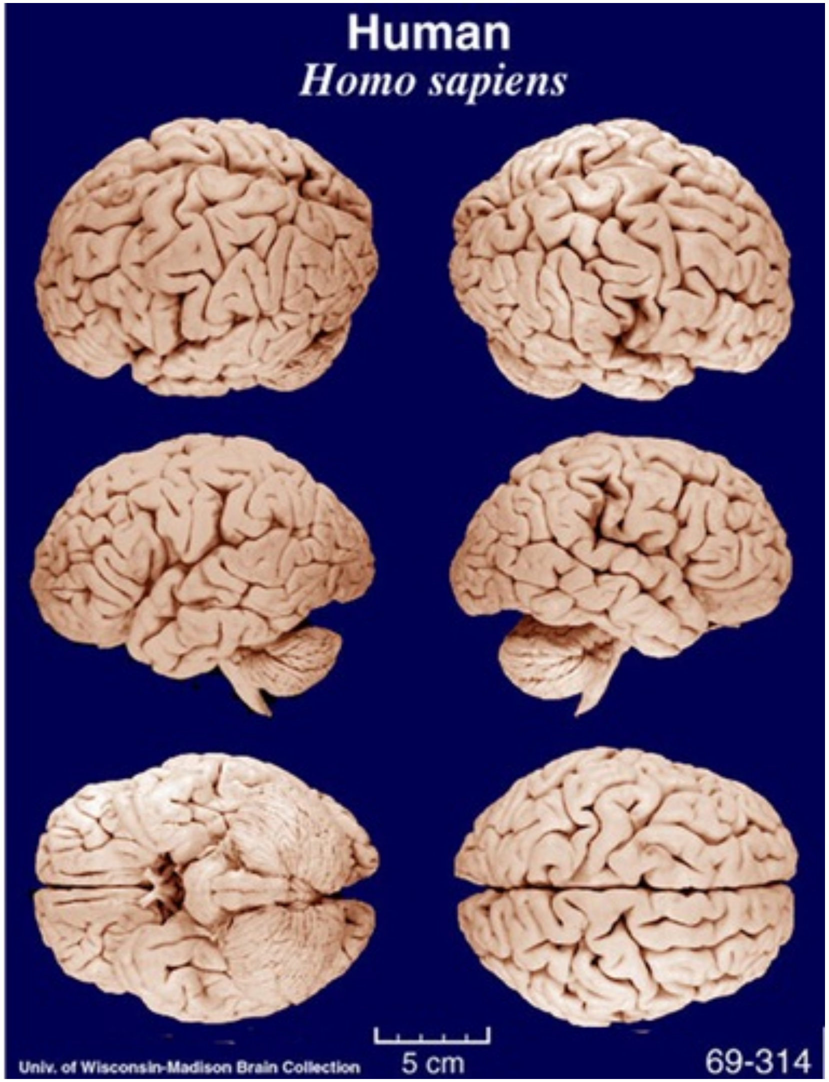


Mirror Cells???

No neurological data…

Asymmetrical Brain



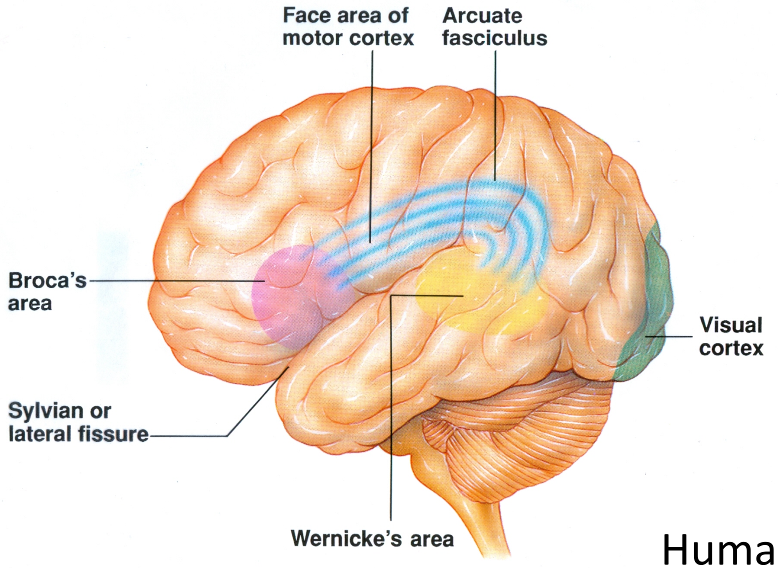


Asymmetrical – Right Hemisphere larger

Asymmetrical – Right Hemisphere Larger

Lateralized??

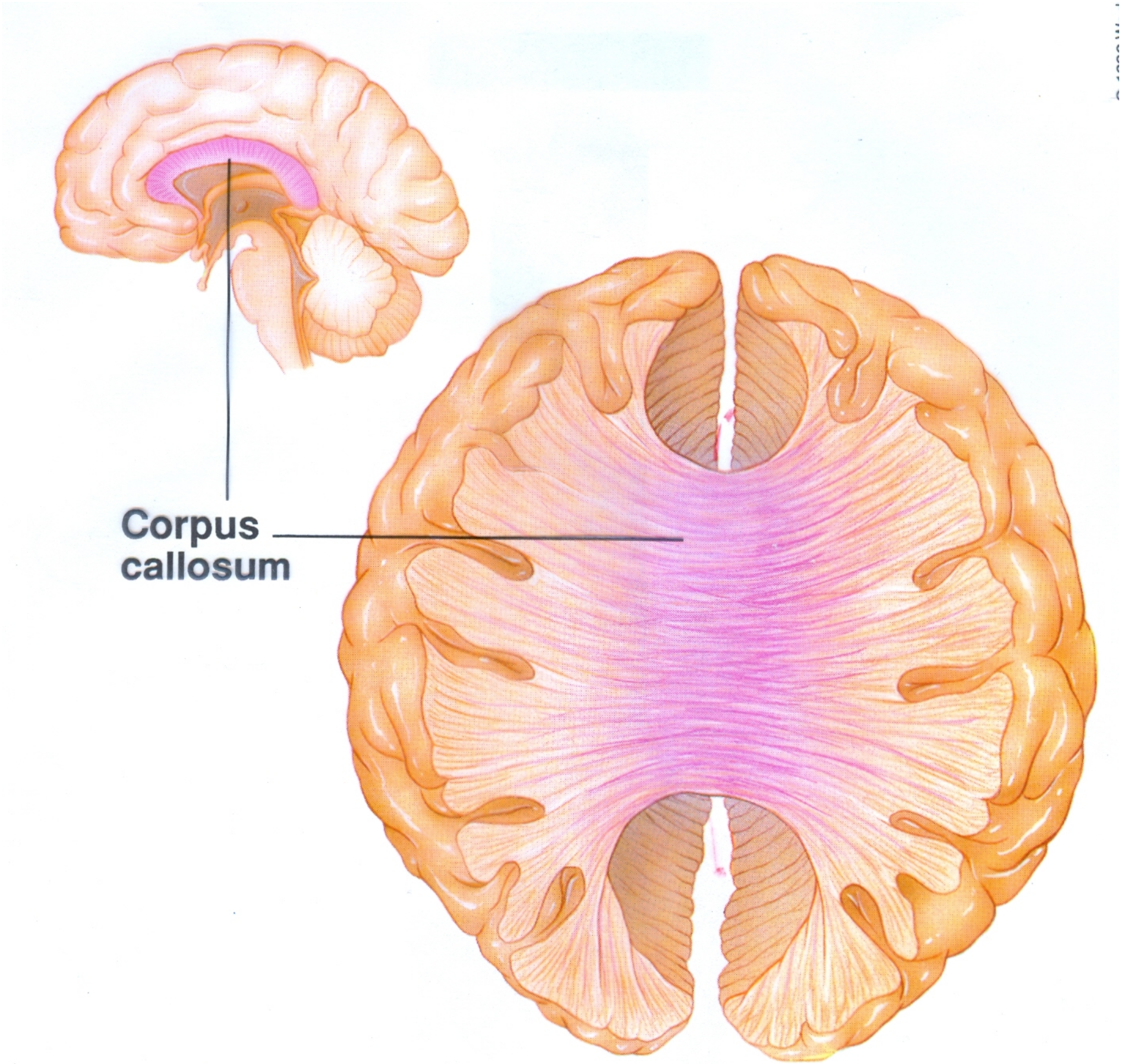
Dolphins preferentially use LEFT eye (RIGHT brain) to look at strangers



Major language areas of cerebral cortex

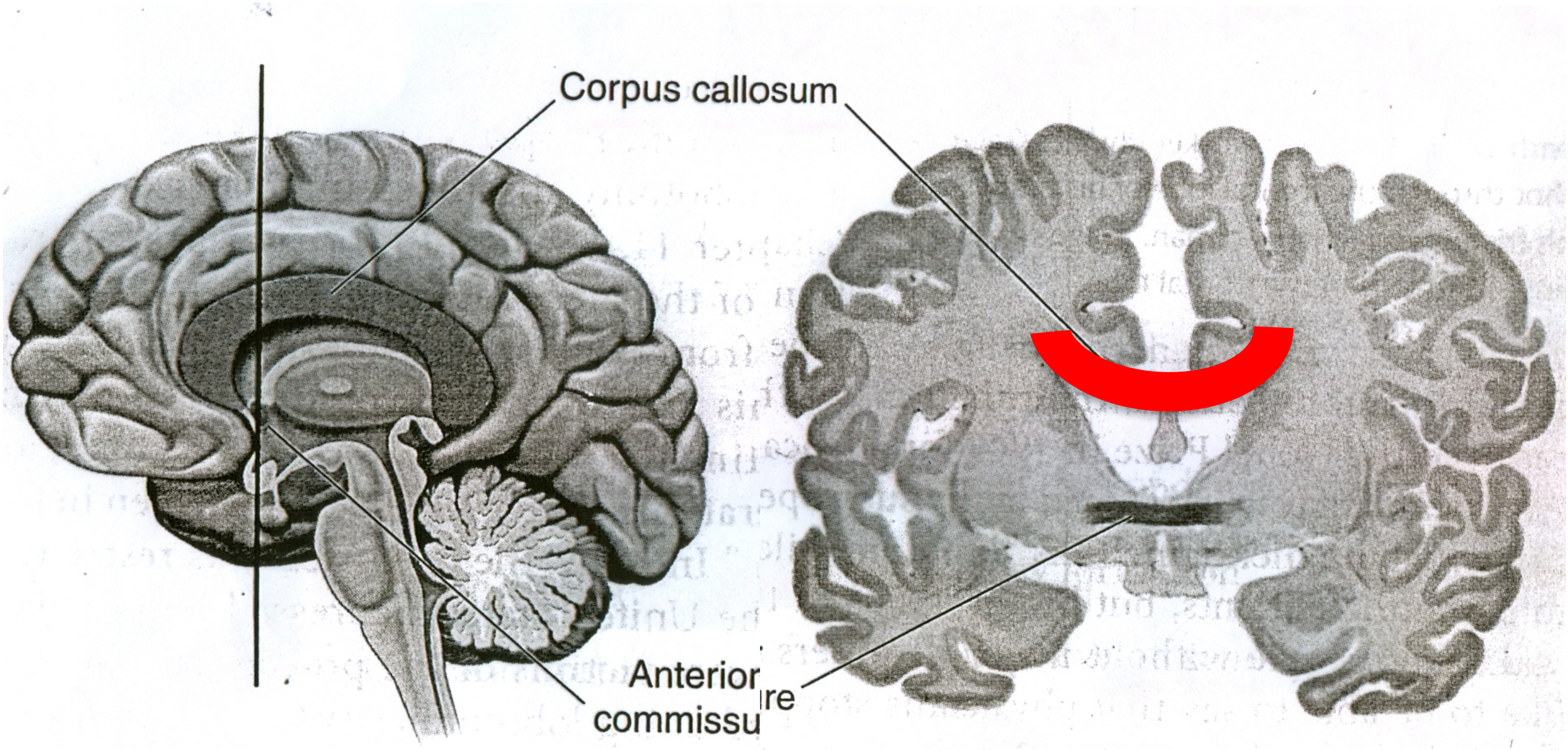
Humans are lateralized to LEFT hemisphere for speech and handedness

Corpus Callosum – Connects 2 hemispheres



Corpus Callosum

Human



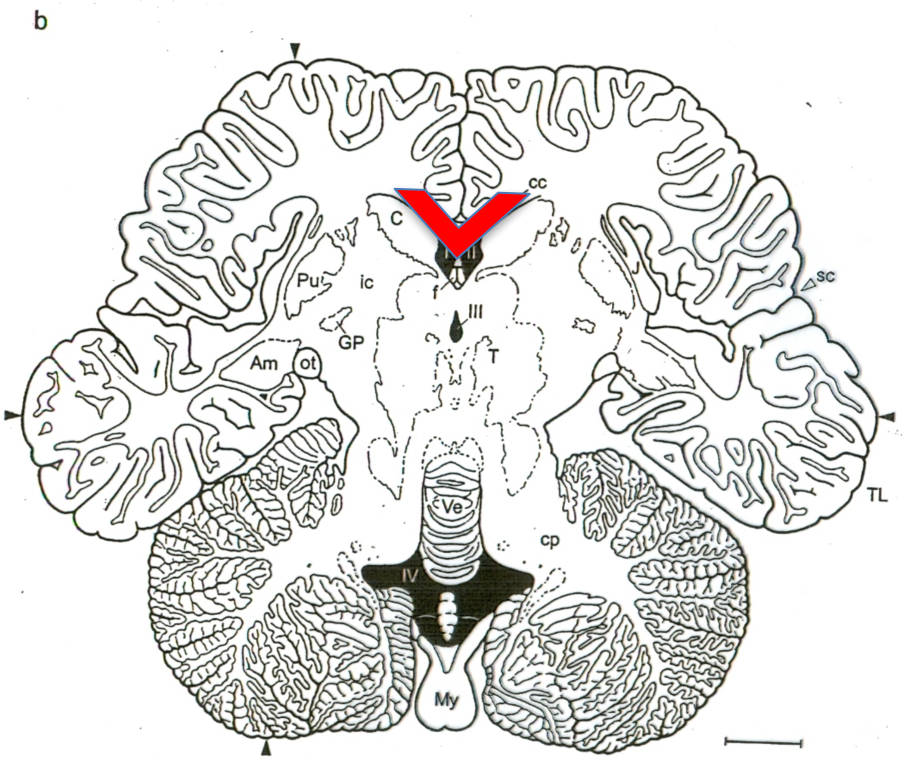
Saggital Section

Coronal Section

Corpus Callosum

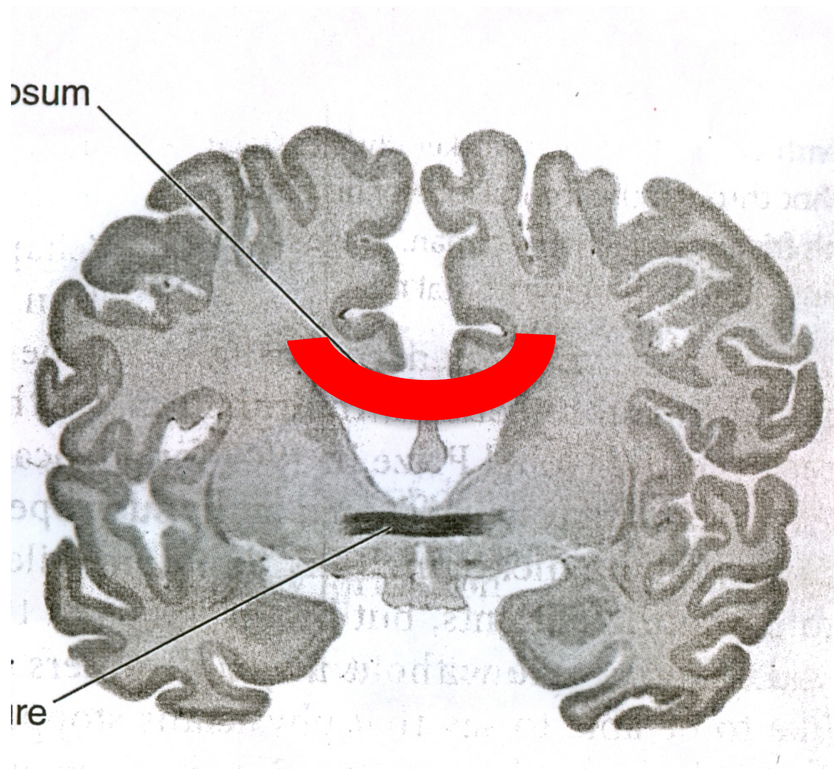
Corpus callosum <u>smallest</u> of ANY mammal!

Bottlenose dolphin
(¼ size of human)



Coronal Section

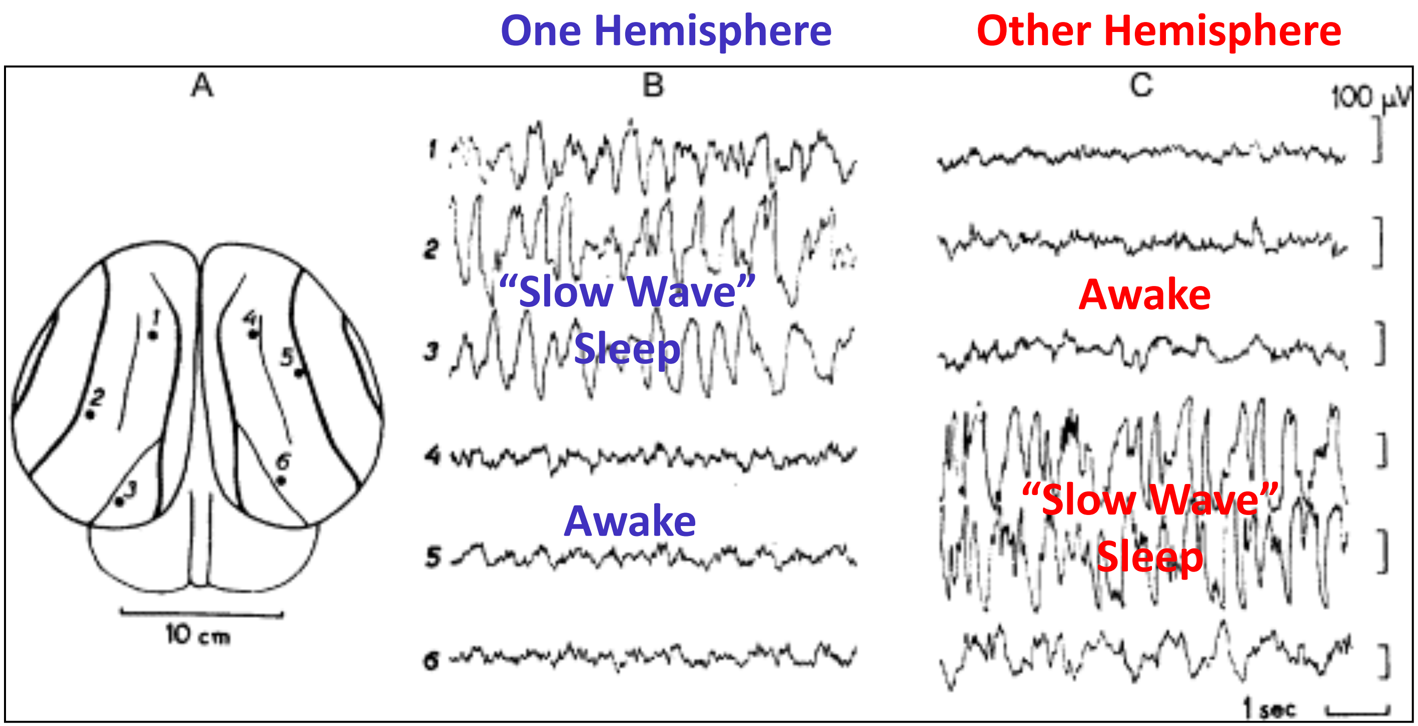
Human



Coronal Section

Sleep EEG

Reduced corpus callosum related to UNI-Hemispheric sleep



Mukhametov, Supin & Polyakova, 1977

One hemisphere must be awake enough to breathe…

Rest with one eye closed, other open…

Plus, No REM!