

# Sensory and Motor Systems

Class #1

# Welcome!

- The primary goal of this course is for you to understand fundamental concepts in the field of sensory and motor neurophysiology.
- It is with these building blocks that you can understand scientific literature and design studies that further our knowledge in this field.

# Office Hours (in your syllabus)

- I will be available from 3:50pm-5pm Tues. and Thurs. after class.
- PLEASE let me know if you plan on coming late after class so I don't wander off the zoom call!!!
- Feel free to email me if you have questions or would like to set up a separate meeting time.

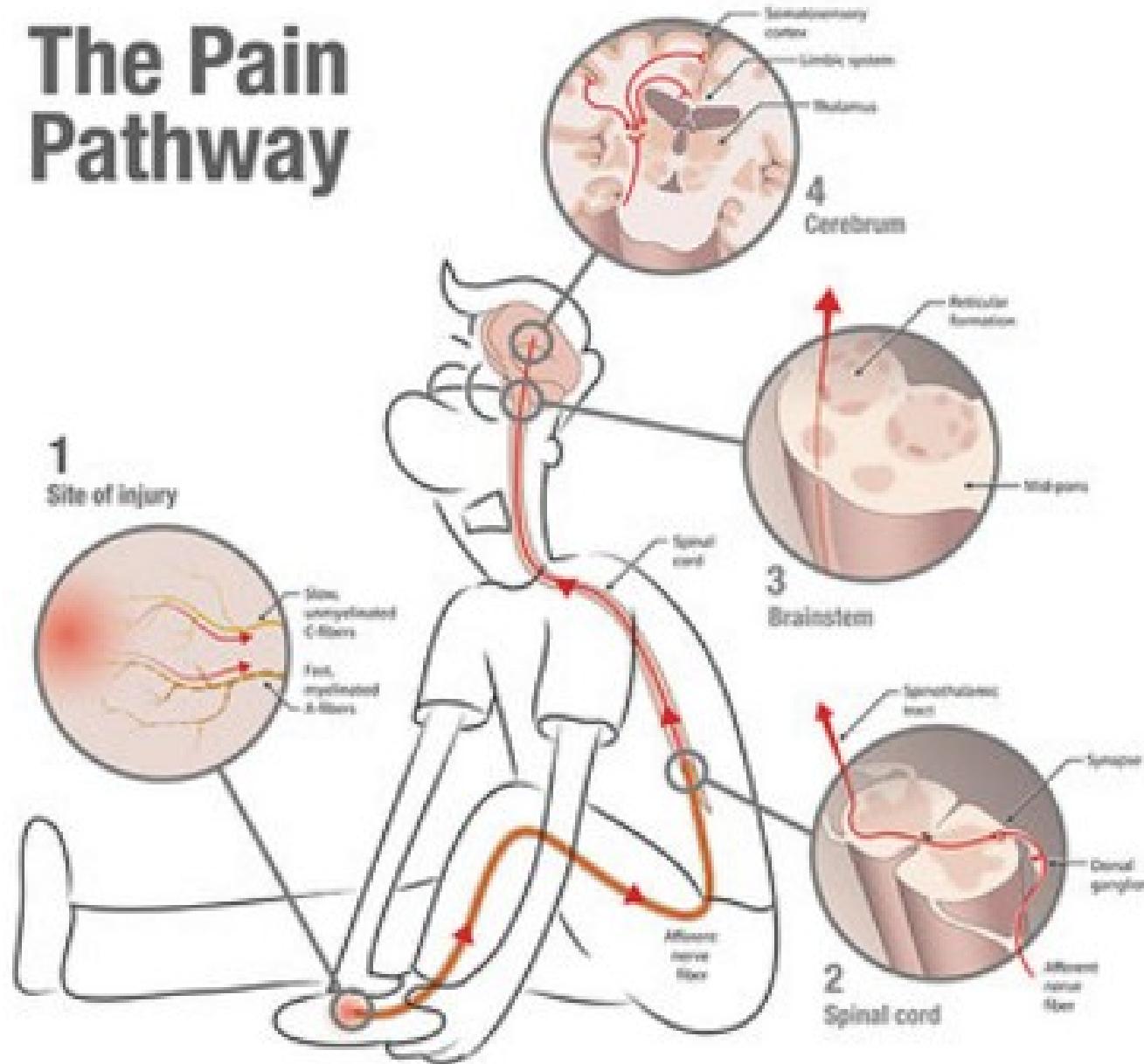
[zemel@pdx.edu](mailto:zemel@pdx.edu)

# Introductions

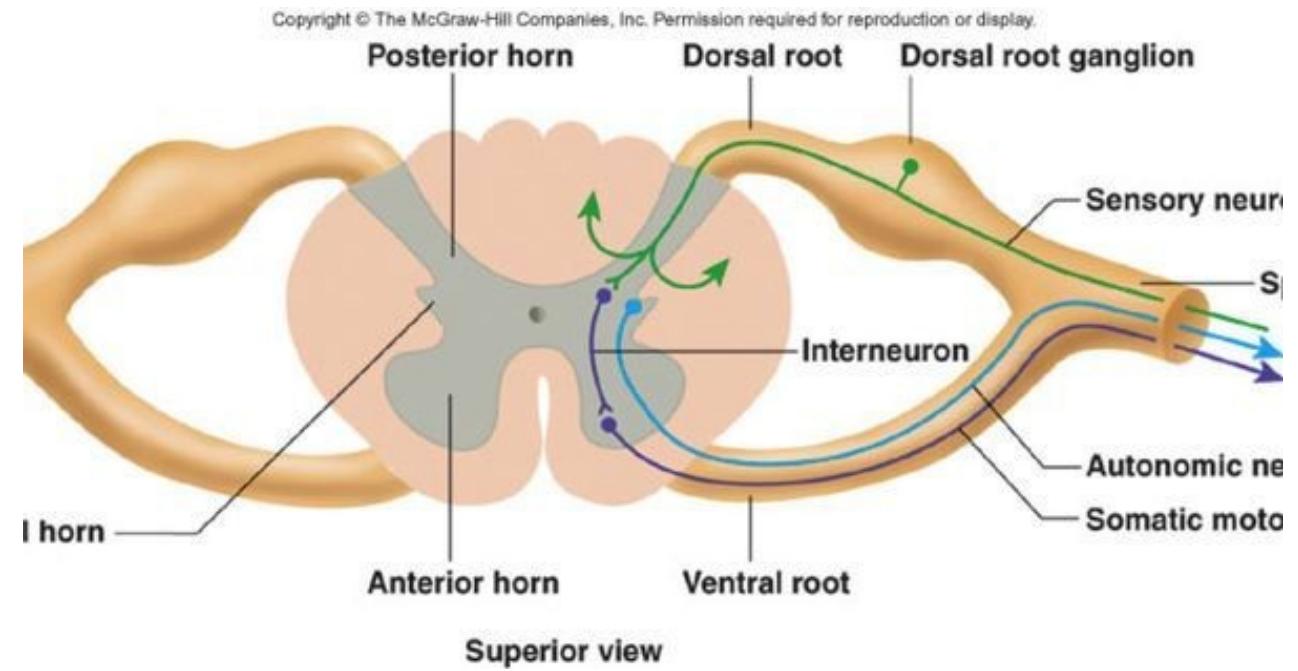
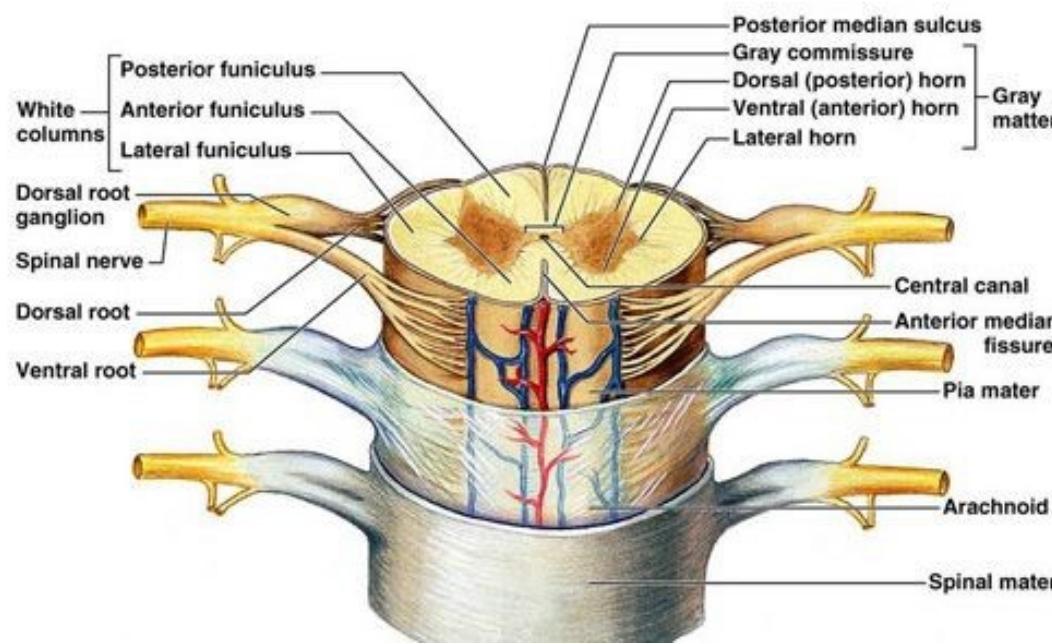
A little about me...

- Graduated from Muhlenberg College in Allentown, PA
- Research Technician at Dartmouth College for ~2 yrs in a respiratory physiology lab
- Ph.D. from Thomas Jefferson University in Neuroscience
- Currently a post-doctoral fellow at OHSU

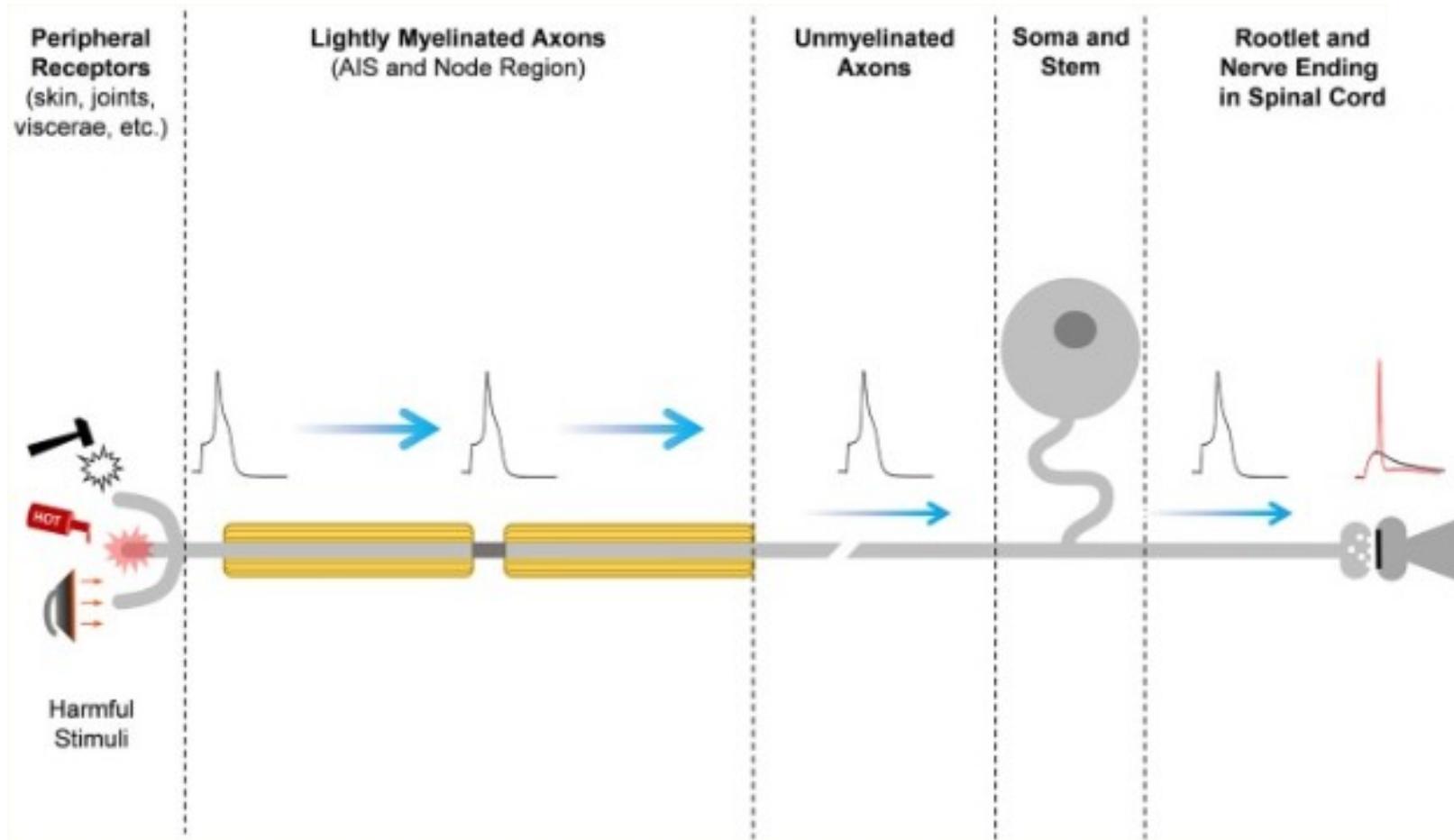
# The Pain Pathway



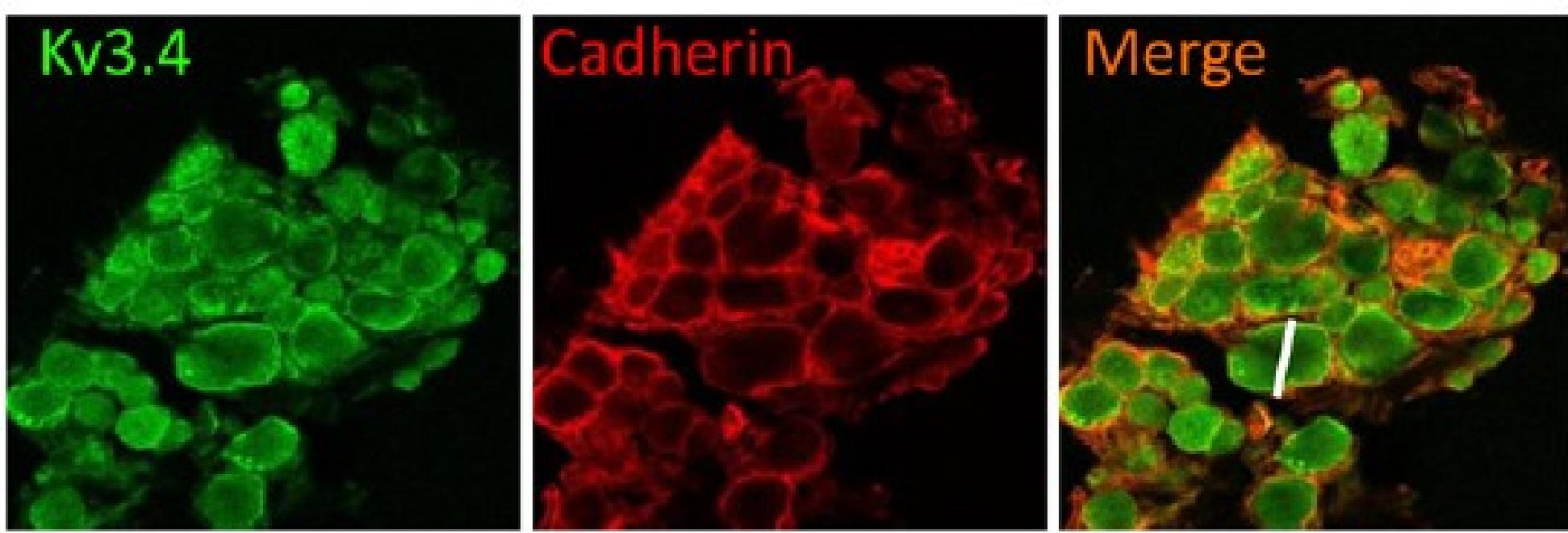
# Pain and the Dorsal Root Ganglia



# Flow of information



# Ion channels in DRG neurons

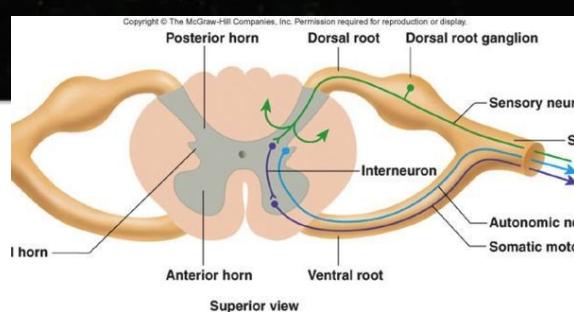
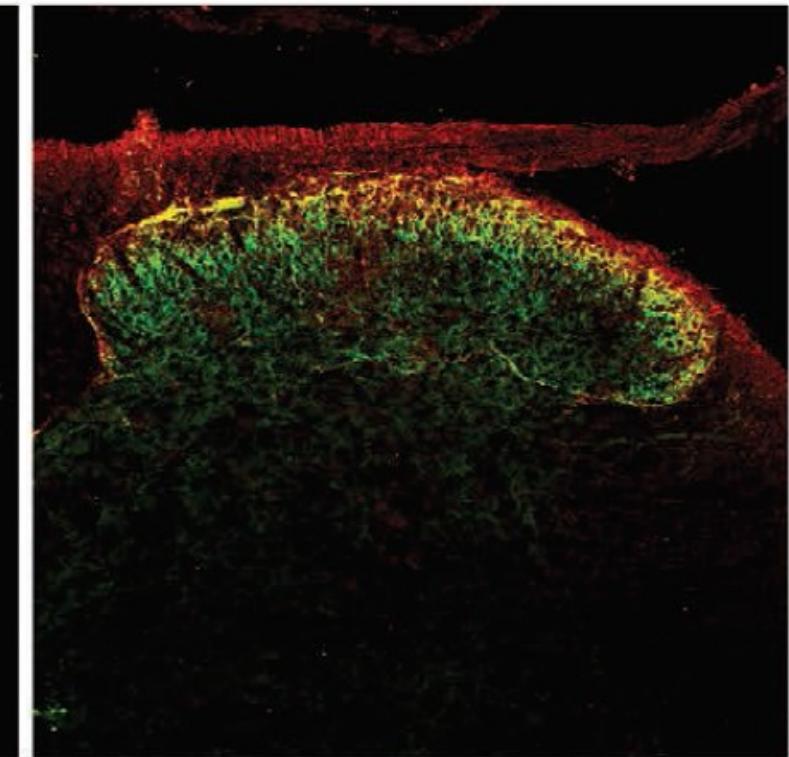
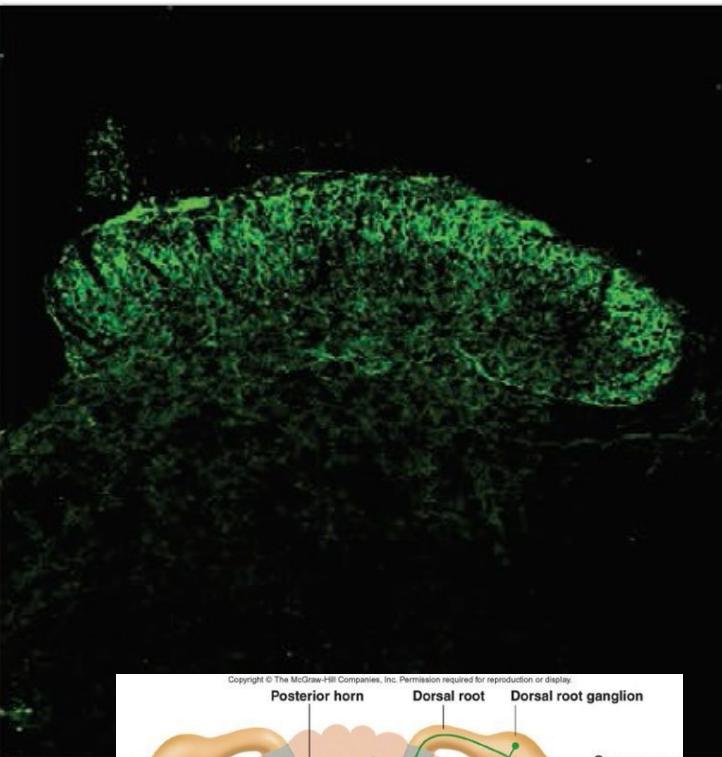
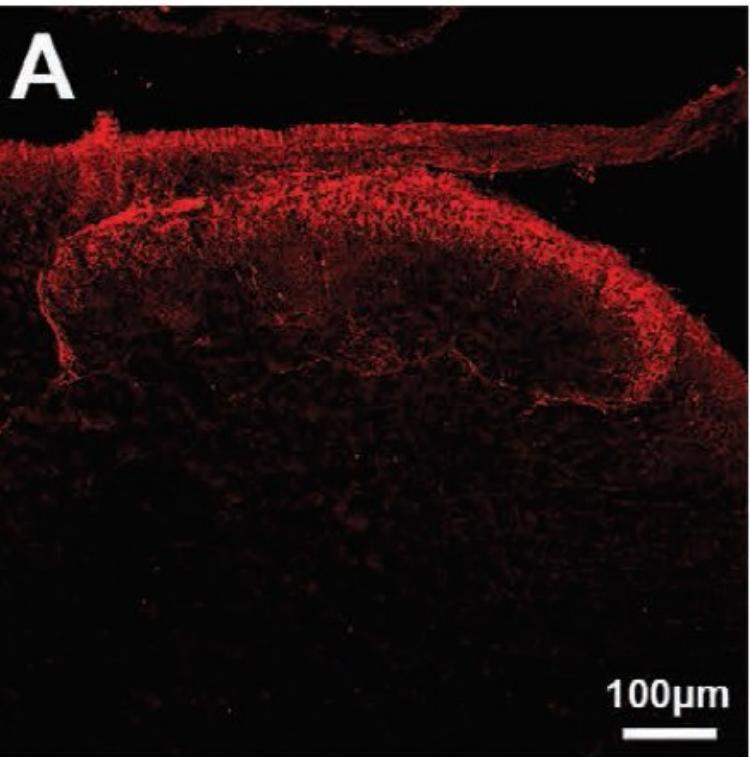


Ritter et al., 2015

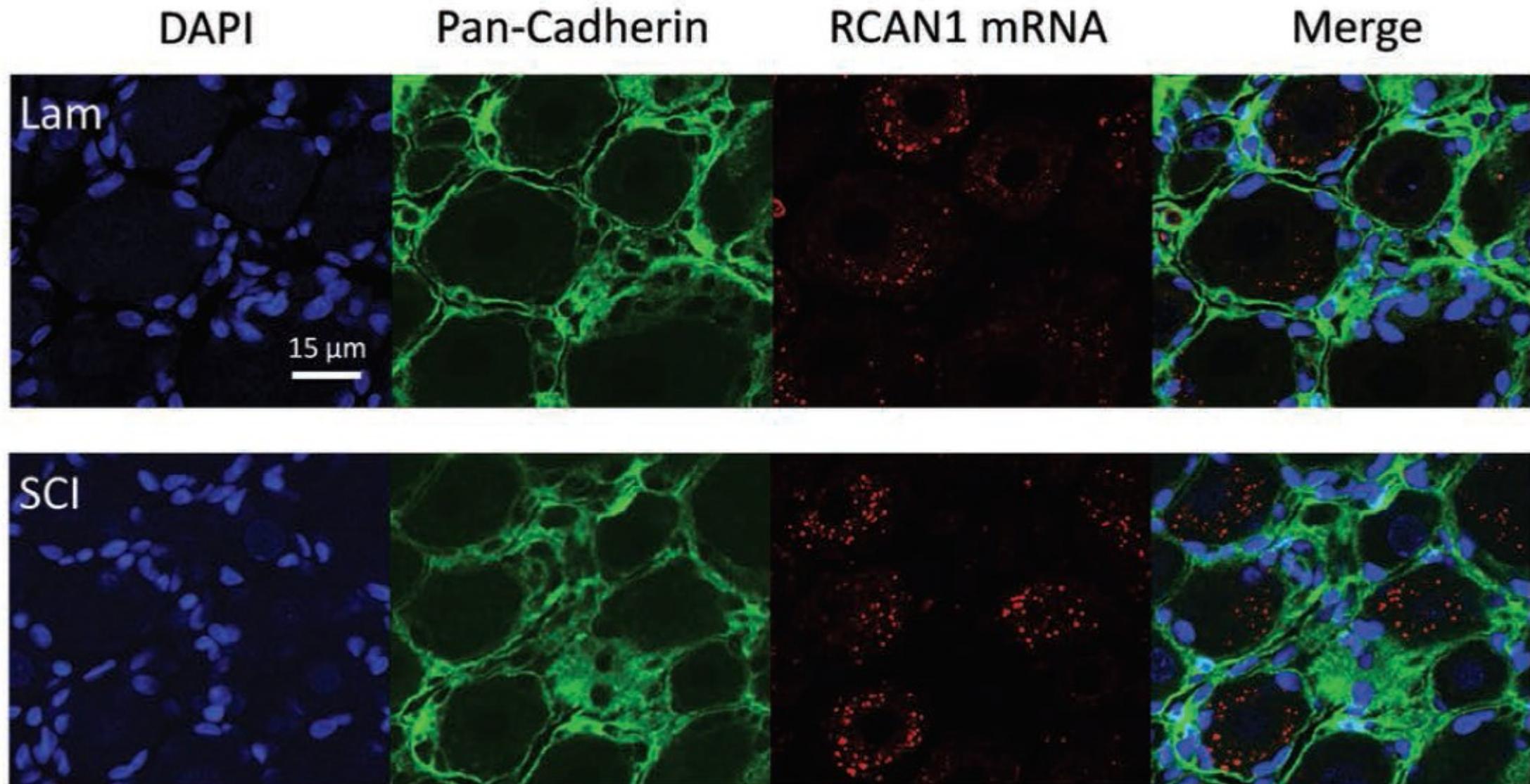
**CGRP**

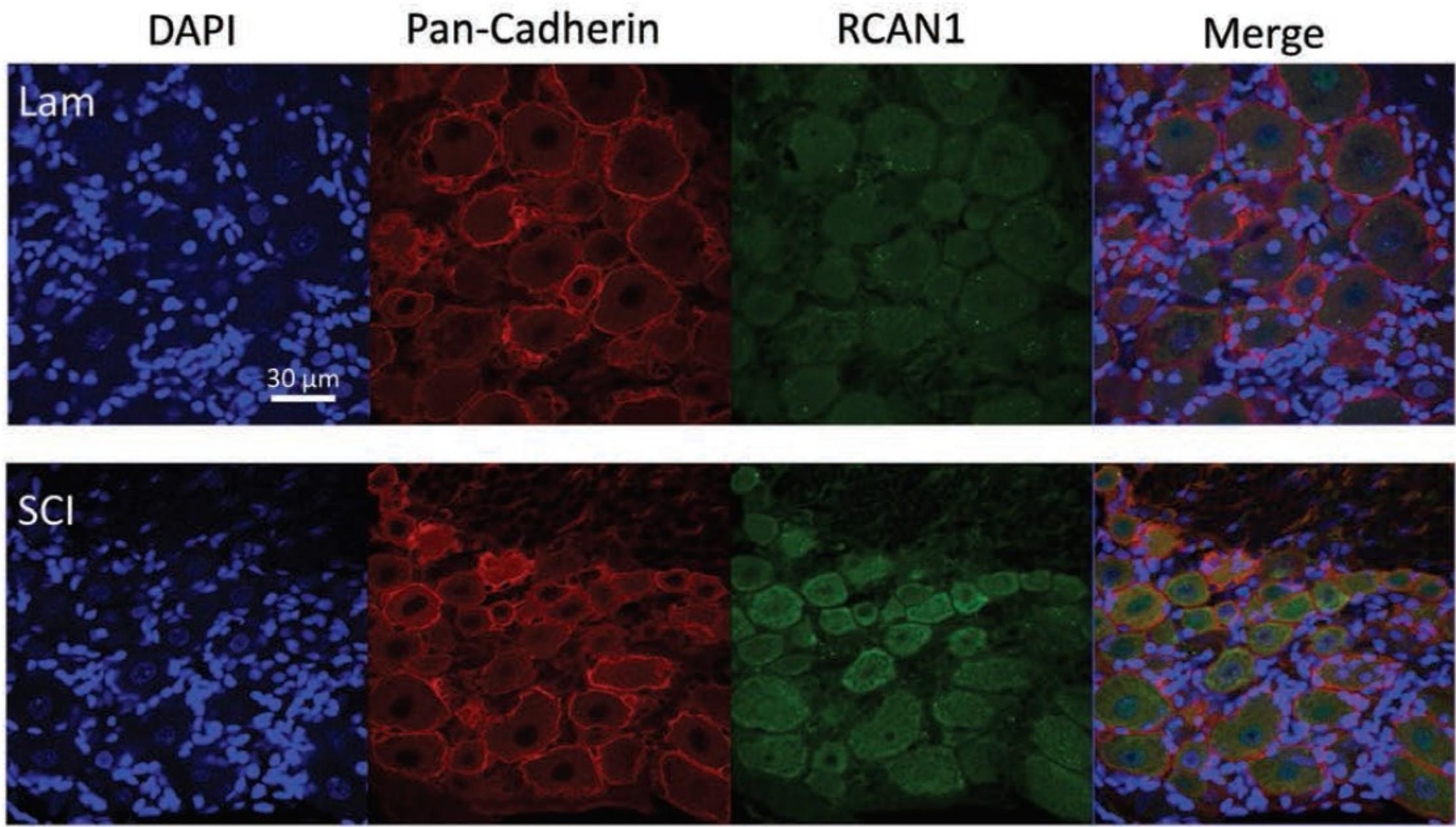
**Kv3.4**

**CGRP / Kv3.4**



Muqeem et al.,  
2018





# Current Research

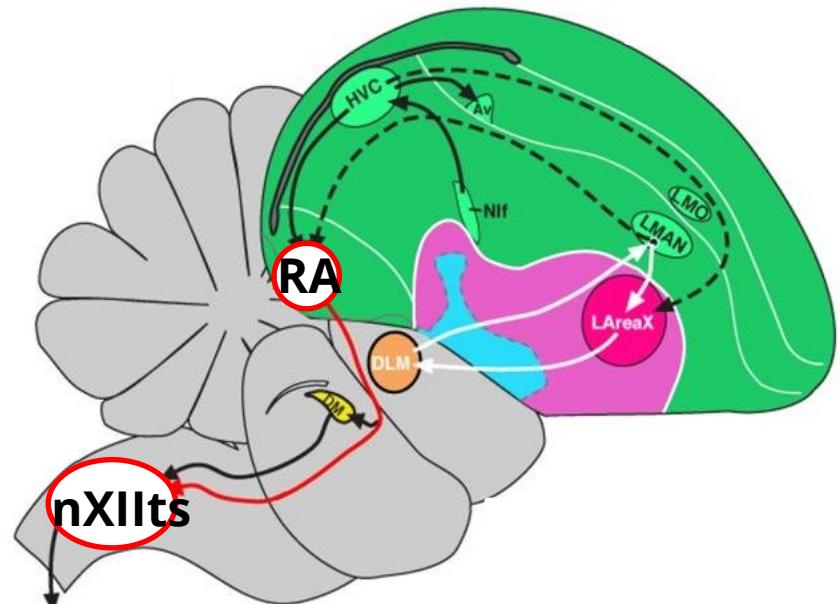
# Song birds and humans are vocal learners



[www.livescience.com](http://www.livescience.com)

<https://www.youtube.com/watch?v=XNCYAZcDuGQ>

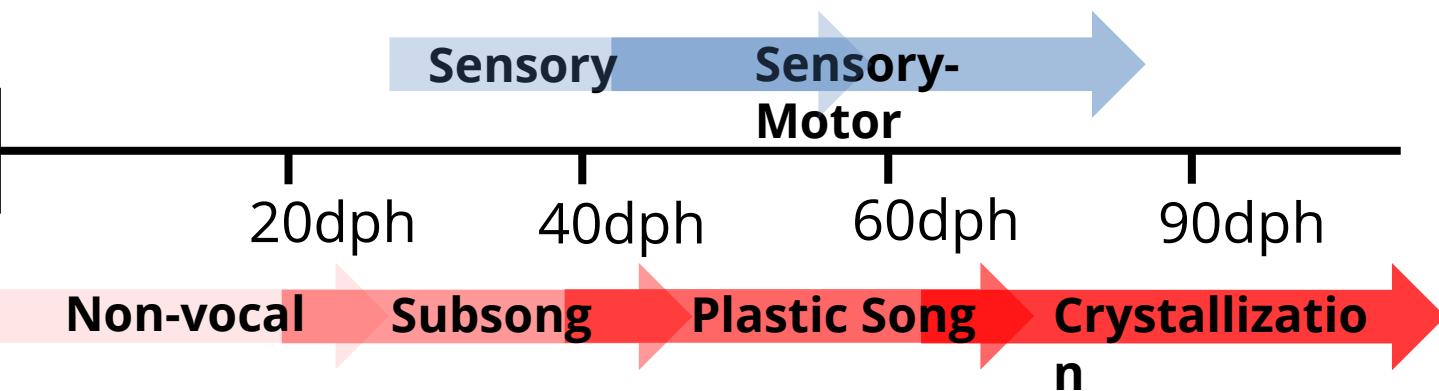
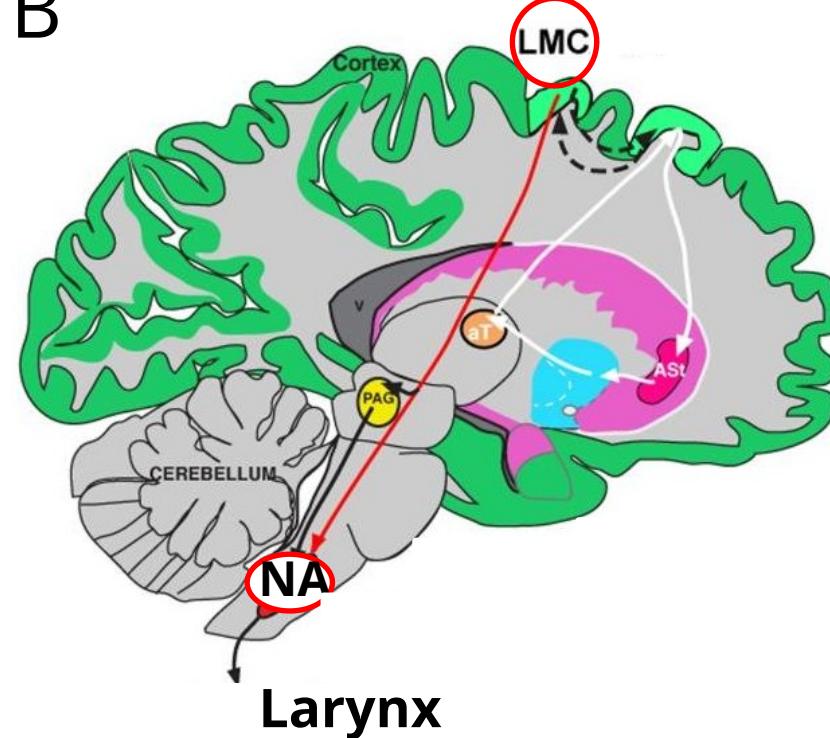
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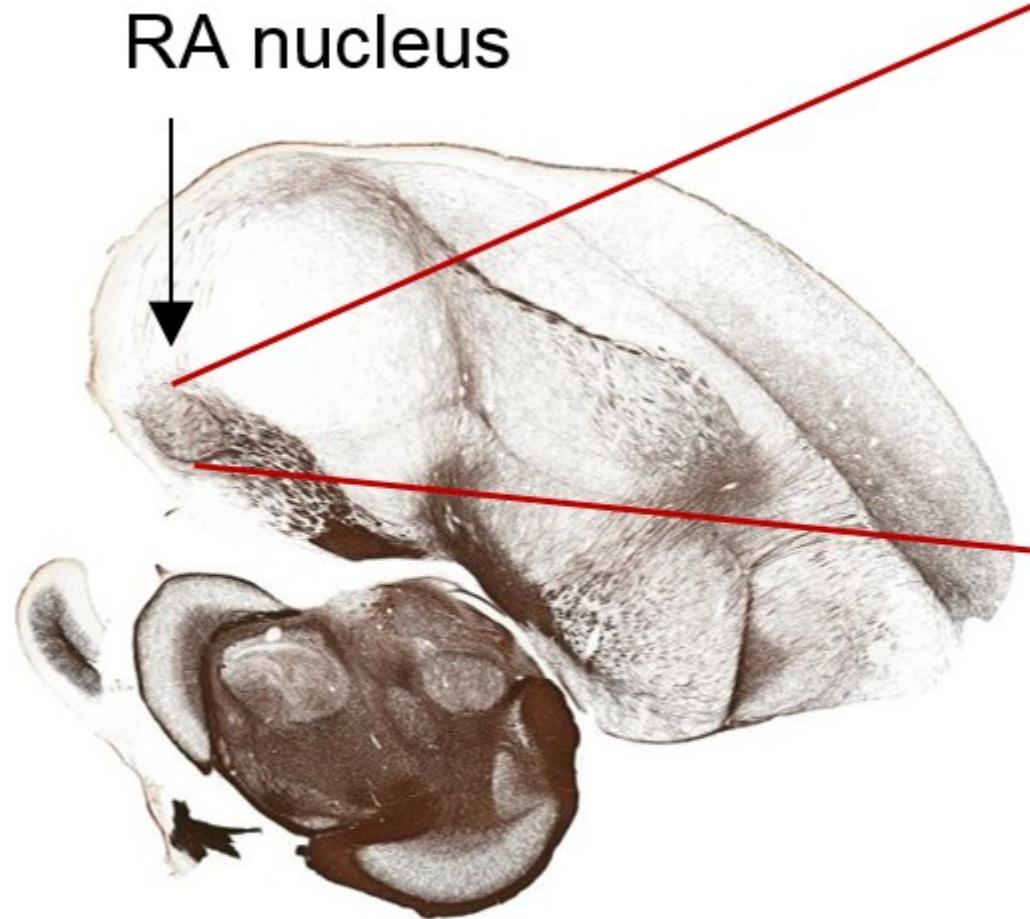


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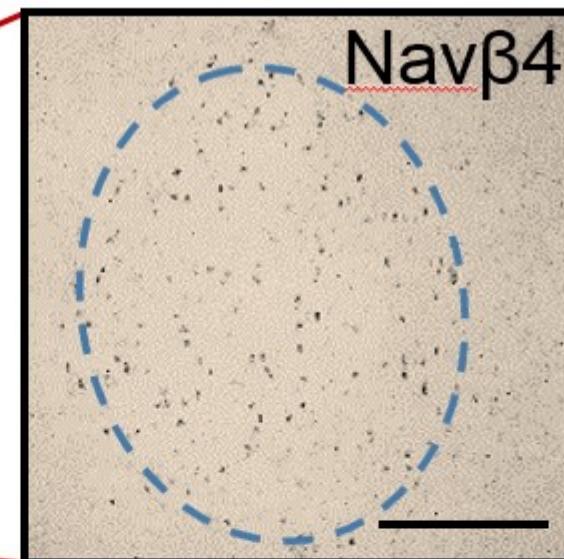


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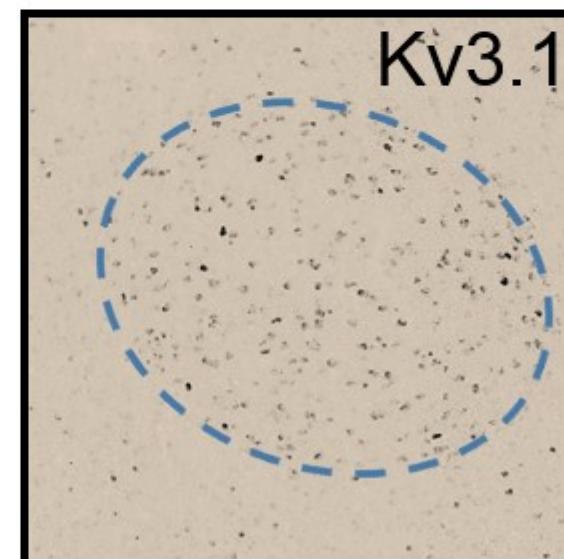
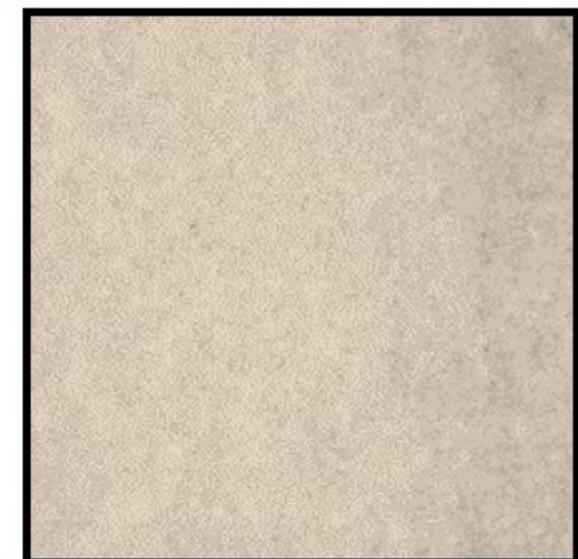


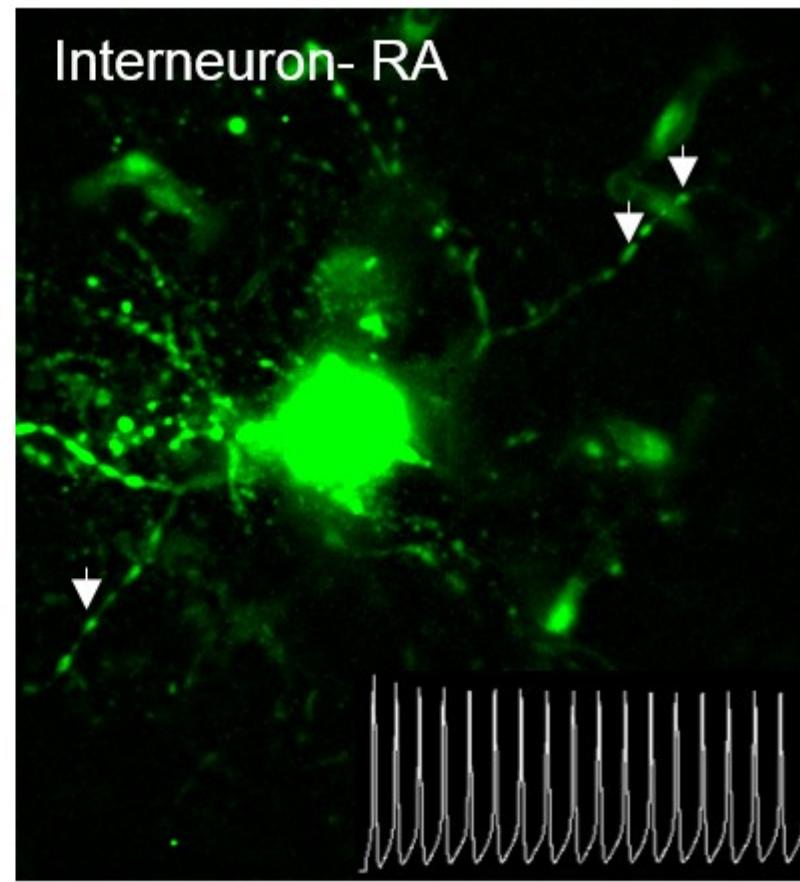
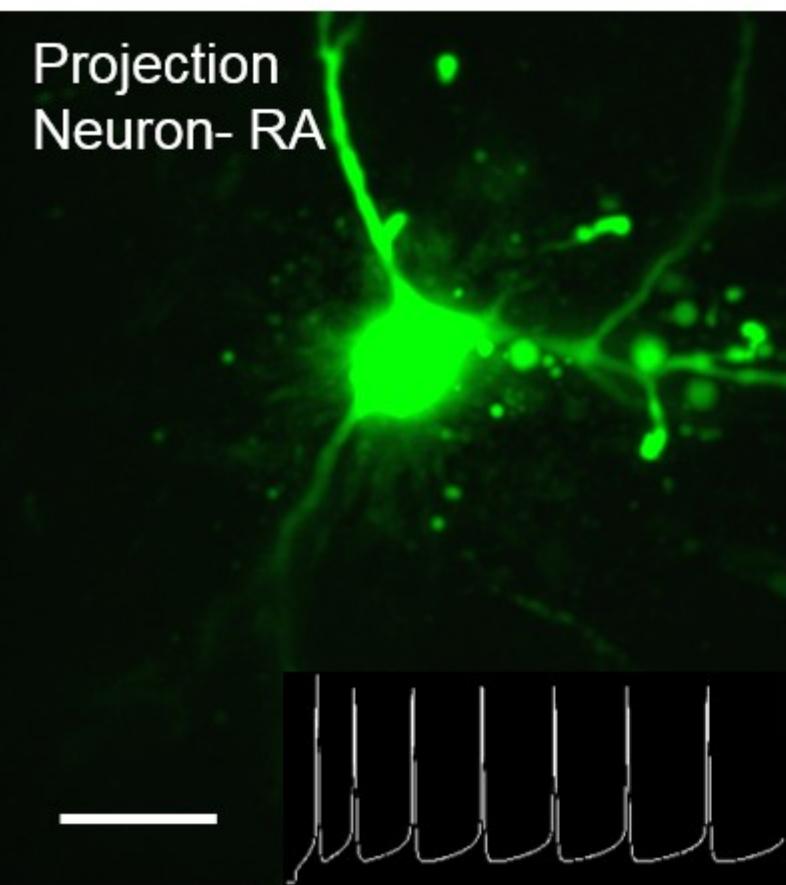


Adult



Juvenile





# Course Expectations (in your syllabus)

## Course Breakdown:

- Quizzes (2) (75 pts)
- Group Presentations (150 pts)
- Midterm (100 pts)
- Final (150 pts)
- Effort (50 pts)
- In class assignments (25 pts)

550 pts total

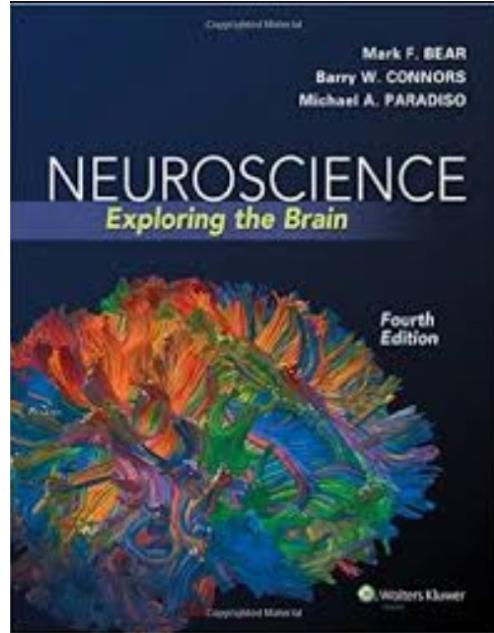
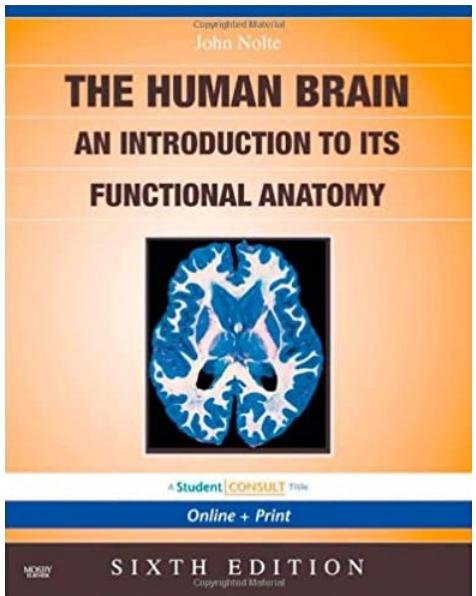
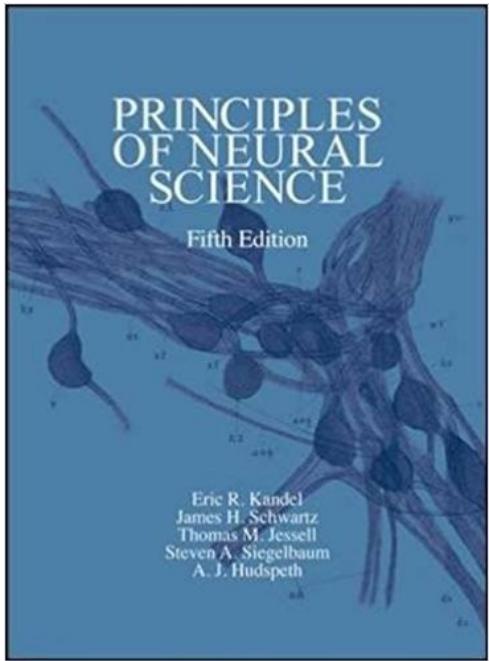
**300 Points do not come from exams!!!!**

# Tools for Class

- Please make sure you have a calculator for the next 2 classes and for exams.
- Although there is not much complex mathematics, a calculator is absolutely necessary for lecture material covering electrical properties of biological membranes.

# Course Expectation (in your syllabus)

- This class covers a lot of information and requires collaborations between students. Therefore, attendance is important.
- You must talk to me ahead of time with a legitimate explanation if a class will be missed and we can make a plan to get you caught up.



# Textbooks

- These textbooks can serve as a supplement to the information taught in this course.
- These are NOT NECESSARY to do well in this course. Exams will be solely based on material covered in the classroom.
- You can find some of these texts via NCBI (google scholar). If you would like me to put any other textbooks on reserve at the library please let me know.

# Course Content

- Neuronal Morphology
- Electrical Properties of Biological Membranes
- Motor, Sensory, Autonomic, Cardiac, Vision and Smell/Taste Physiology
- Topics in Neurodegenerative Disease

# Group projects

- I have selected a number of potential topics for each group to select from to present to the class.
- I will now split you into 7 groups in breakout rooms. Introduce yourselves to one another and spitball a few topics you may be interested in covering.

# Group Projects

- **Your group will send me 2 potential choices by the third class period.**
- Your group must email me with a brief outline of your project with me **~5 days** before your presentation to make sure things are on the right track.
- **It is your responsibility to stay on top of these dates.**
- Those not presenting should be engaged during presentations as this information will show up on the final exam.

# Group Projects

- **It pays to find your groups and get started early!!!**  
The first group will present on the 12<sup>th</sup> class period and I will use a random number generator to determine the order of presentations.
- I also will keep in mind that the 1<sup>st</sup> group has the difficult situation of A) the time constraint and B) setting the pace for these presentations for the rest of the class.

Lets take a look at the guide

This will inform your presentations and your adherence to the recommendations should ensure a good grade

# Quizzes

- There are 2 quizzes listed on the syllabus that will cover information from class. Always come prepared with a calculator.
- These quizzes will be a reality check of sorts for how you are progressing in the course.
- The first quiz contains  $\frac{1}{2}$  the information of the second and is therefore  $\frac{1}{2}$  the points.

# Exams

- There will be one midterm exam and a final exam.
- I will hold review sessions during the class before for each exam.

# Class participation

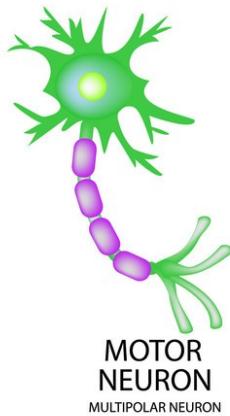
- You are encouraged to be an active, engaged member of this class.
- This part of your grade will be determined by your attendance, engagement, and effort, both in and out of class.
- **MANDATORY ATTENDANCE** for group presentations will add to this grade!!

# Some Background Information

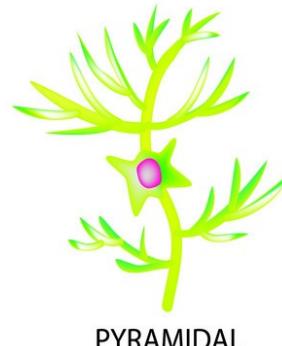
## TYPES OF NEURONS



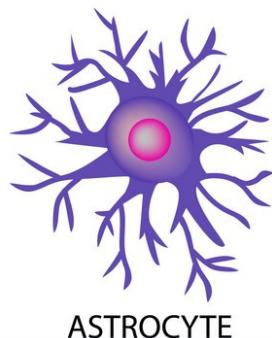
SENSORY  
NEURON  
UNIPOLAR NEURON



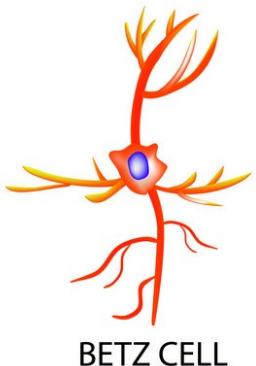
MOTOR  
NEURON  
MULTIPOLAR NEURON



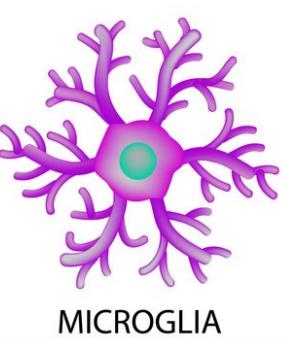
PYRAMIDAL  
NEURON



ASTROCYTE

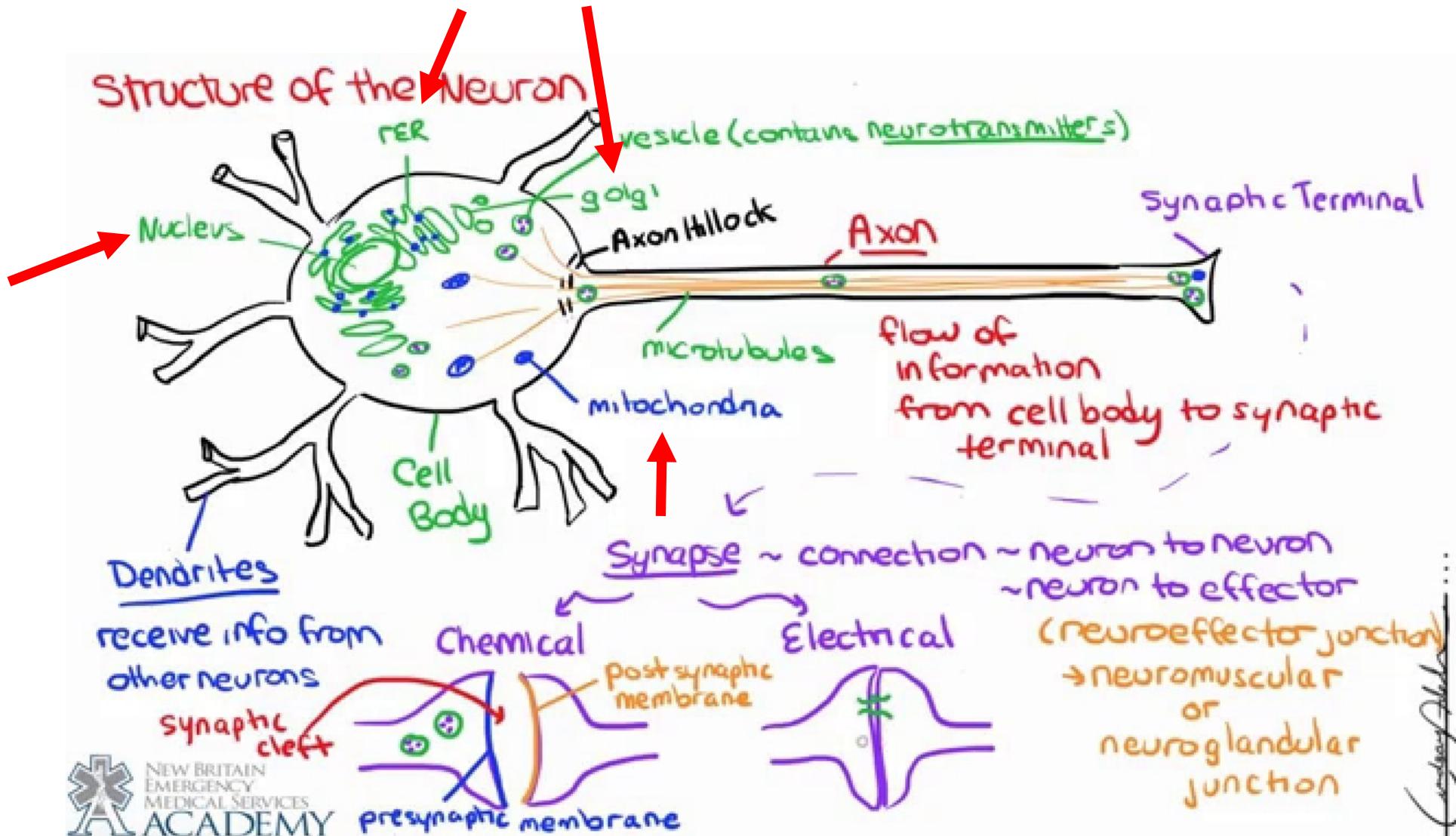


BETZ CELL



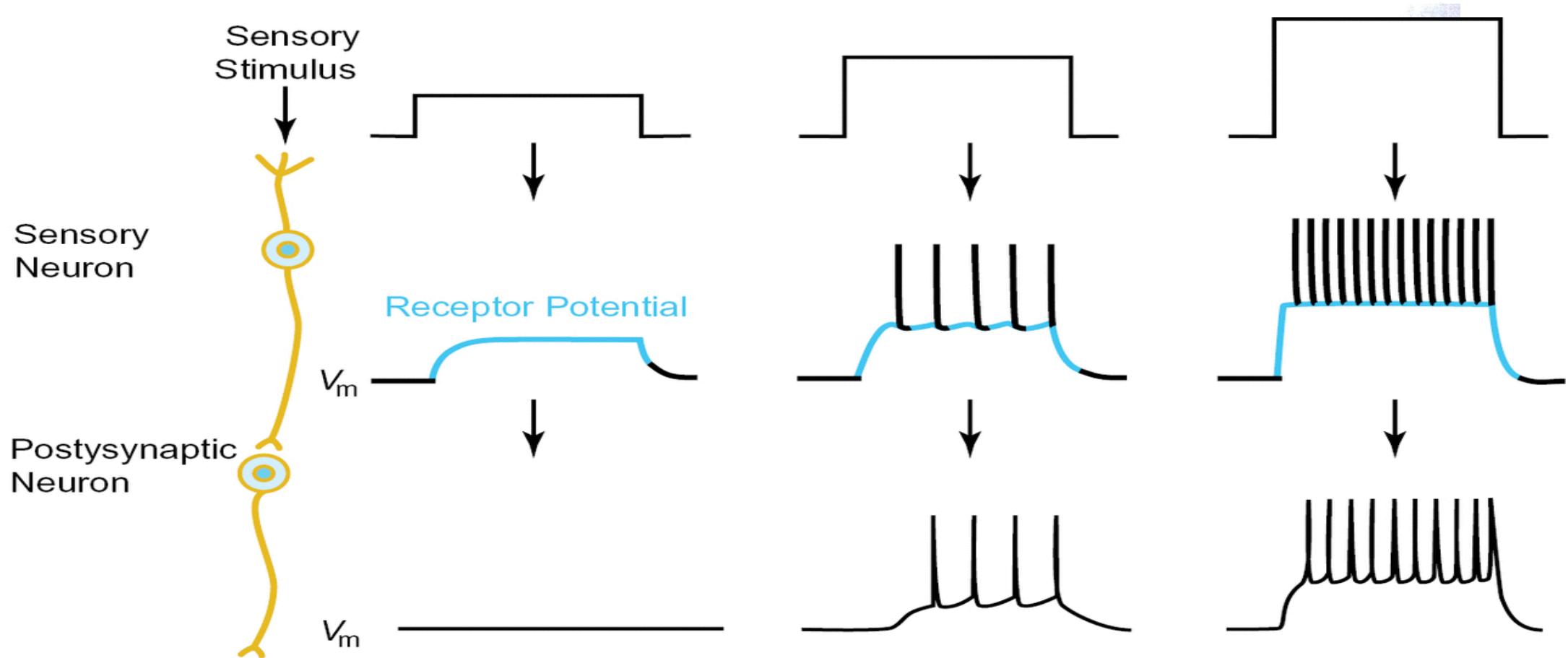
MICROGLIA

- Neurons are another type of cell.
- As a baseline you may want to refresh yourself with some basic cell biology.
- Despite many different cell-types there are many common themes.



# Frequency Modulation of Neural Information

Spike frequency is proportional to stimulus intensity

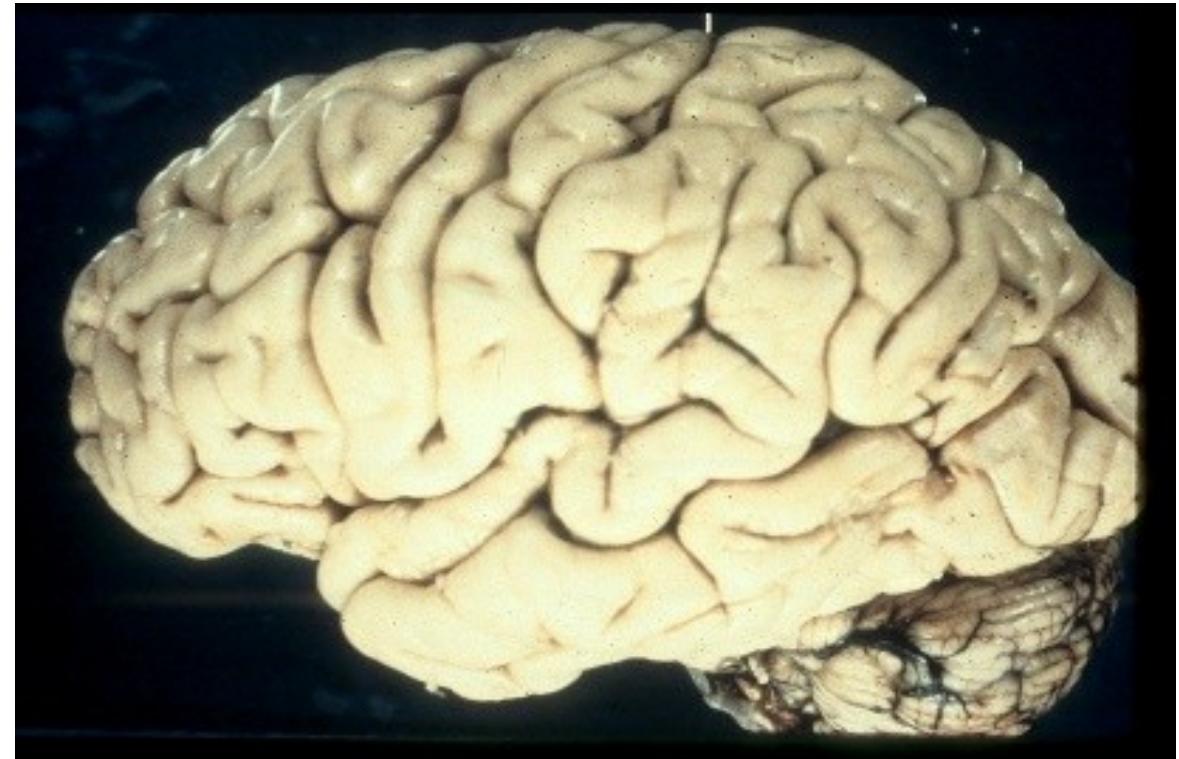


Levitin and Kaczmarek, *The Neuron*, Oxford, 2015

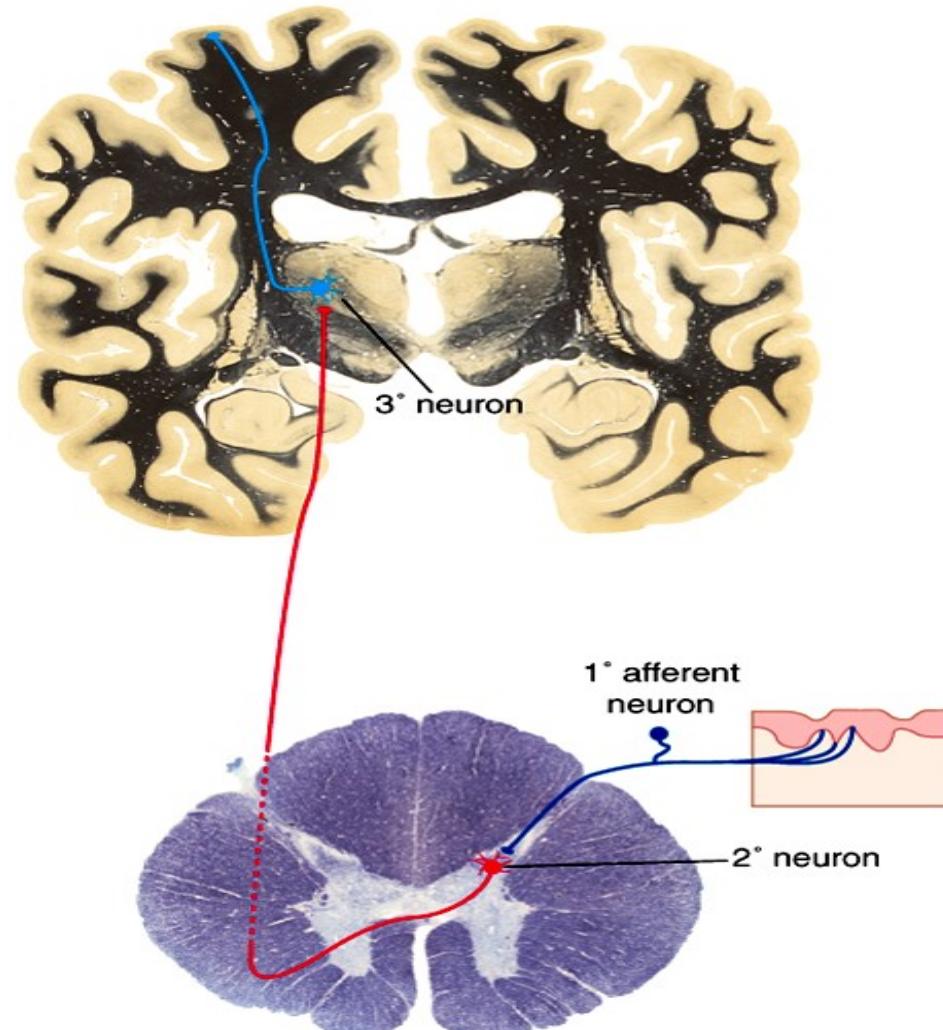
# CNS Development and Organization

## Learning objectives

- Identify major components and overall organization of the CNS
- Learn basic neuroanatomic terminology
- Identify CNS gross anatomic surface features



- **Structures**
  - What is it called?
  - Where is it?
  - What is it connected to?
  - What does it do?
- **Relationships**
  - Linear (pathways)
  - Three dimensional (surface/internal)
  - Systematic (structure/function)
  - Diagnostic (lesion/defect)

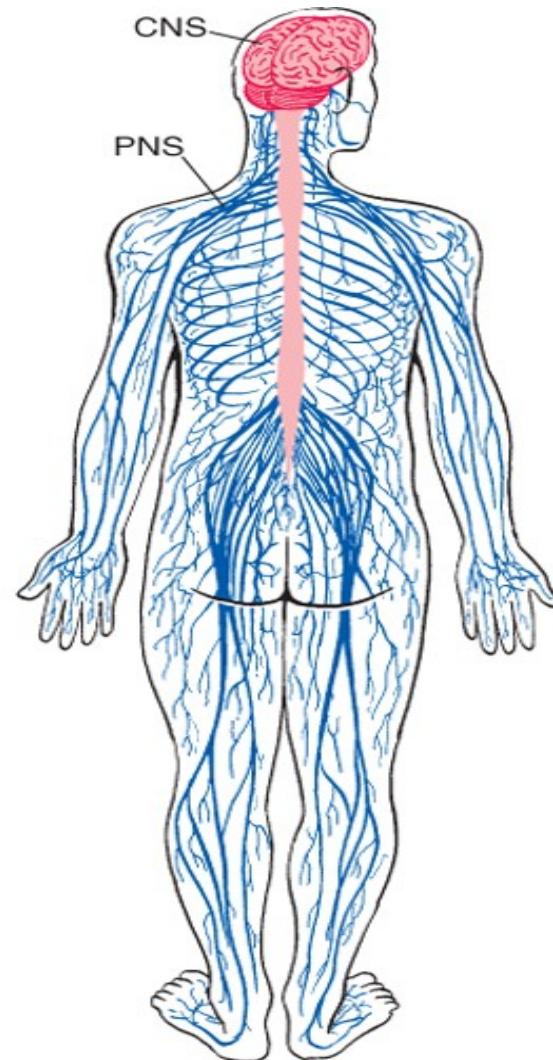


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**For example:**  
**The Thalamus**  
**And**  
**Spinal Cord**  
**The Spino-thalamic Pathway**

# Components of the Nervous System

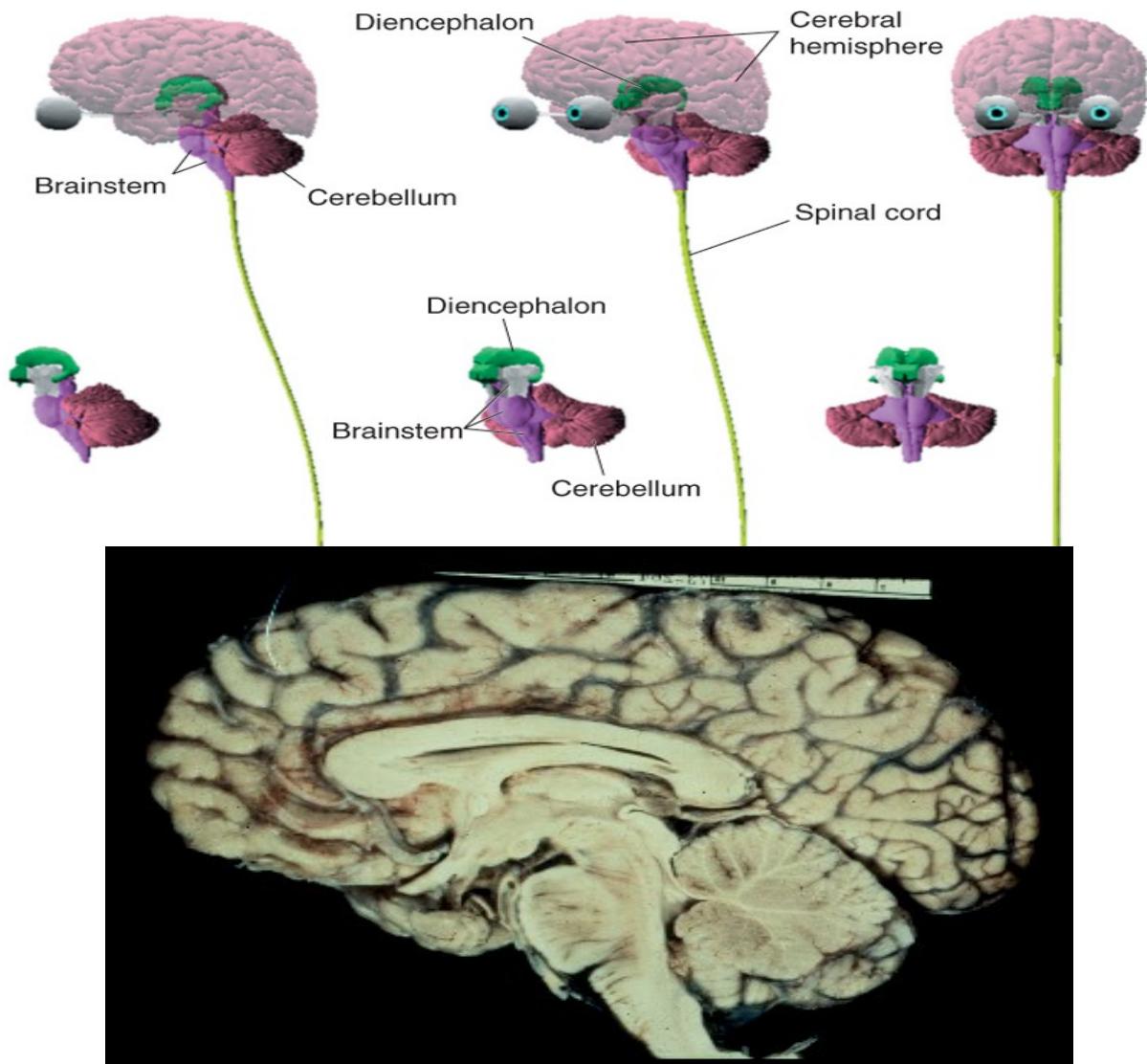
- **Central Nervous system**
  - Brain
  - Spinal cord
- **Peripheral Nervous system**
  - Ganglia
    - Spinal or dorsal root
    - Sympathetic
    - Parasympathetic
    - Enteric
  - Nerves and nerve fibers
    - Sensory afferents
    - Motor efferents



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# Major Components of the CNS

- **Brain**
  - **Cerebrum**
    - **Cerebral hemispheres**
      - Cerebral cortex
      - Basal ganglia
    - **Diencephalon**
      - Thalamus
      - Hypothalamus
  - **Cerebellum**
  - **Brainstem**
    - Midbrain
    - Pons
    - Medulla
- **Spinal Cord**



# Terminology Associated with CNS Anatomy

- **Planes of dissection**

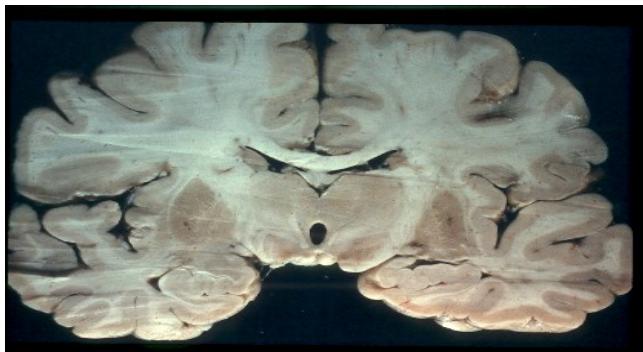
- Sagittal
- (hemisection; parasagittal)
- Coronal (frontal)
- Horizontal



WHOLE



SAGITTAL



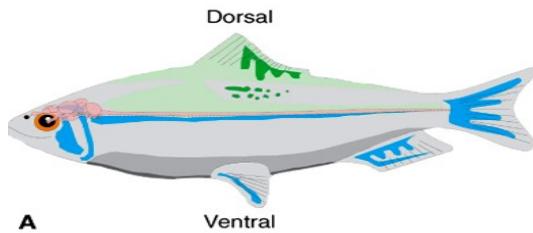
CORONAL



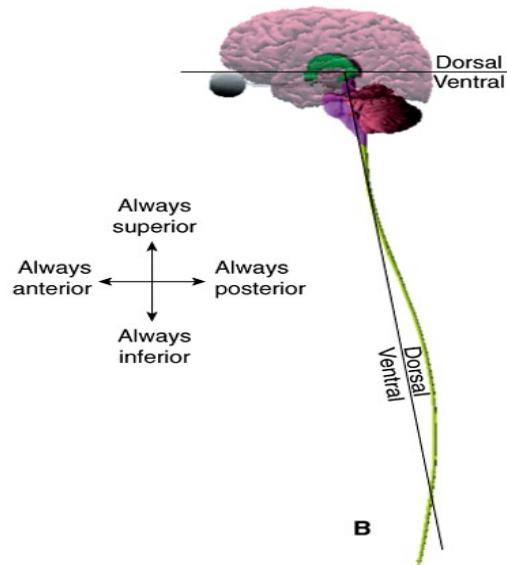
HORIZONTAL

- **Study tip:** begin with putting labels on structures, then progress to two-dimensional relationships, then to three-dimensional relationships, pathways, and function.

# Terminology Associated with CNS Anatomy



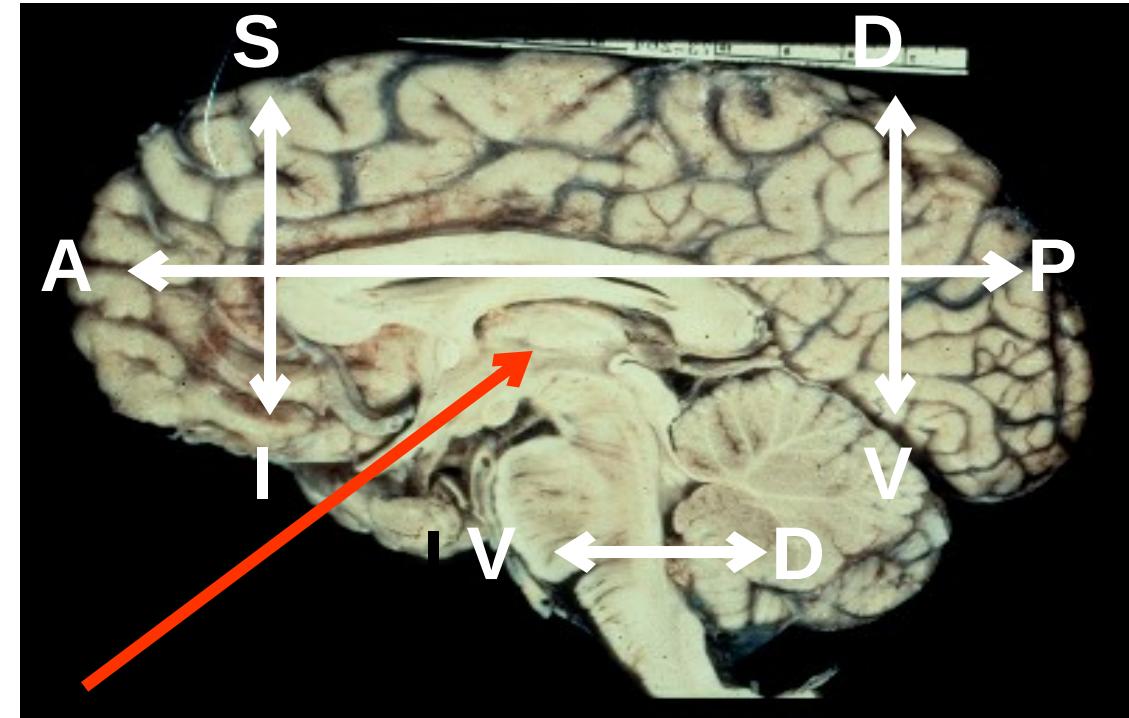
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## Directions

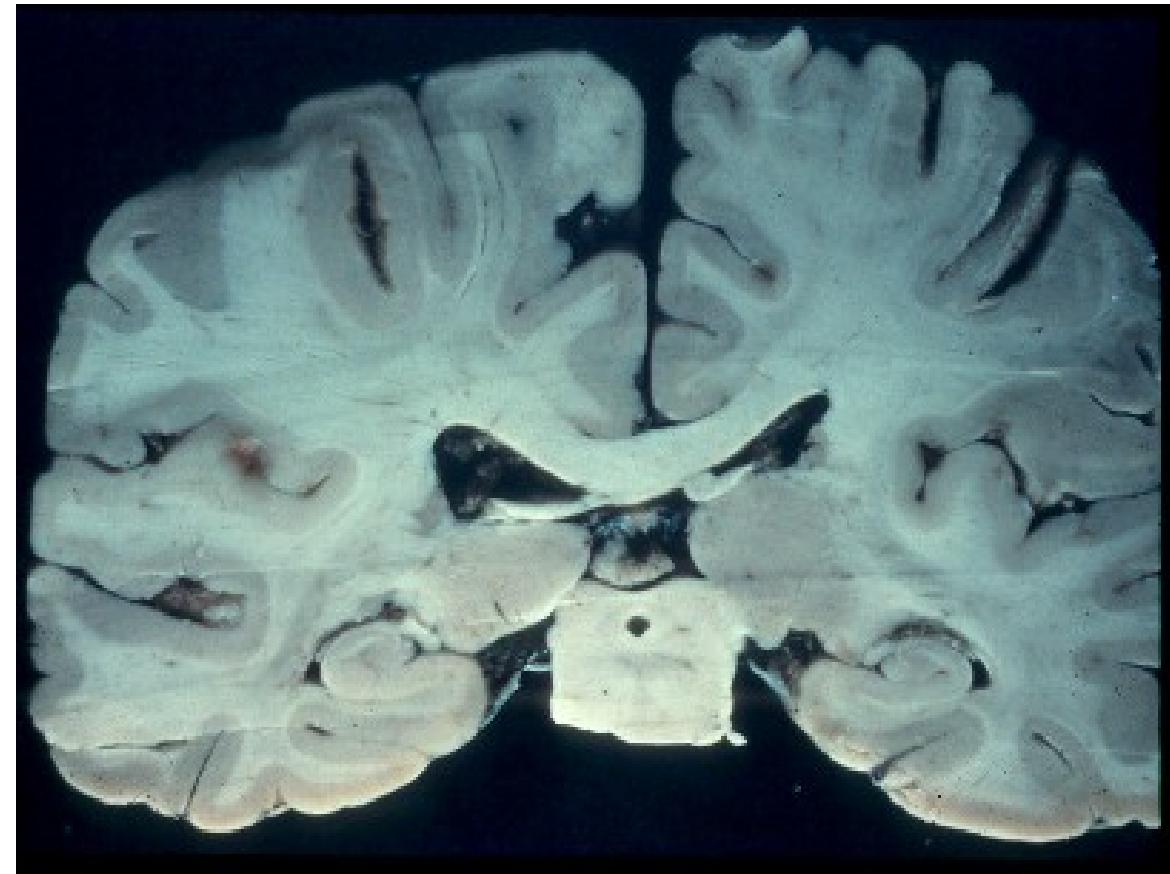
- Dorsal/ventral
- Superior/inferior
- Anterior/posterior



- Directions change at cephalic flexure at level of midbrain

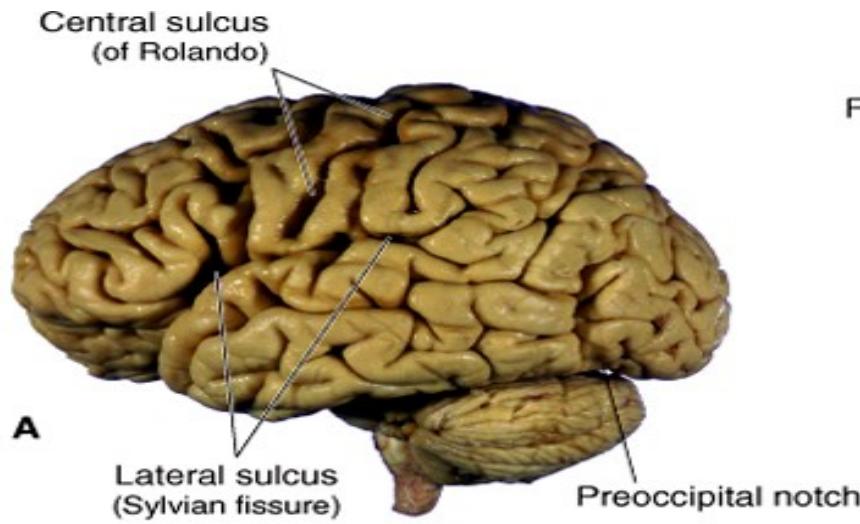
# Terminology Associated with CNS Anatomy

- **Gray matter**
  - Cell bodies and neuropil
  - Terms: cortex (laminar), nucleus, body, center, etc. (clustered).
- **White matter**
  - Myelinated fibers
  - Terms: tract, commissure, etc.

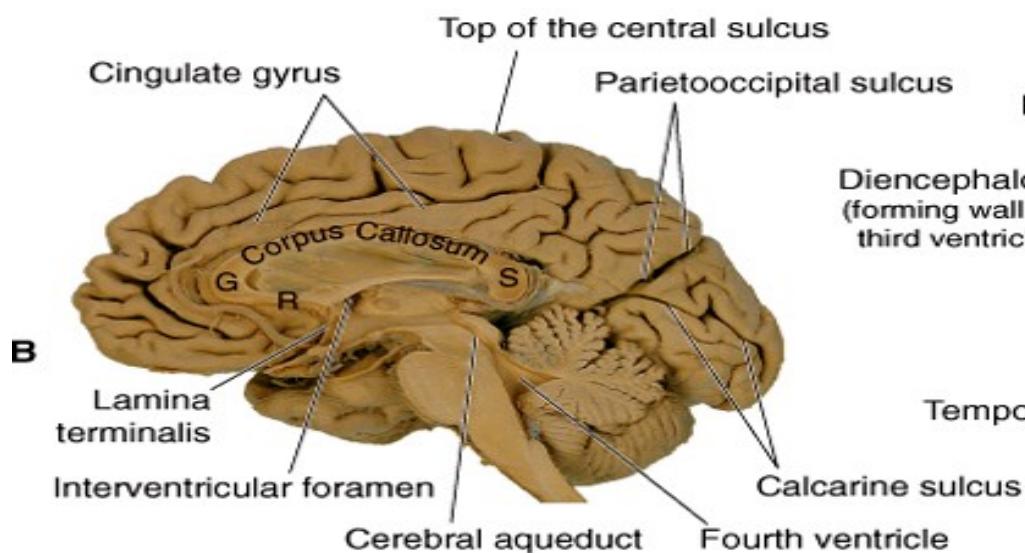
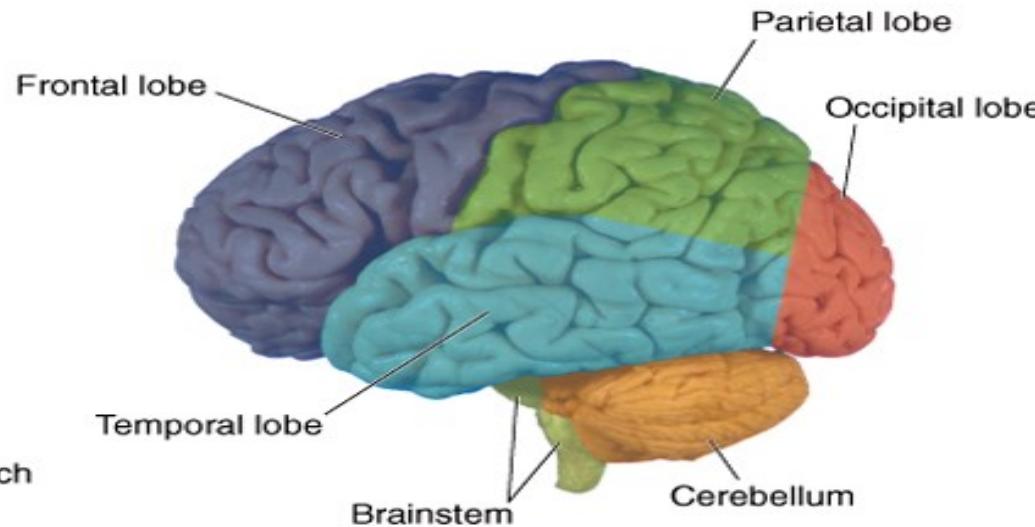


GROSS: UNSTAINED

# Lobes of the Cerebral Hemispheres

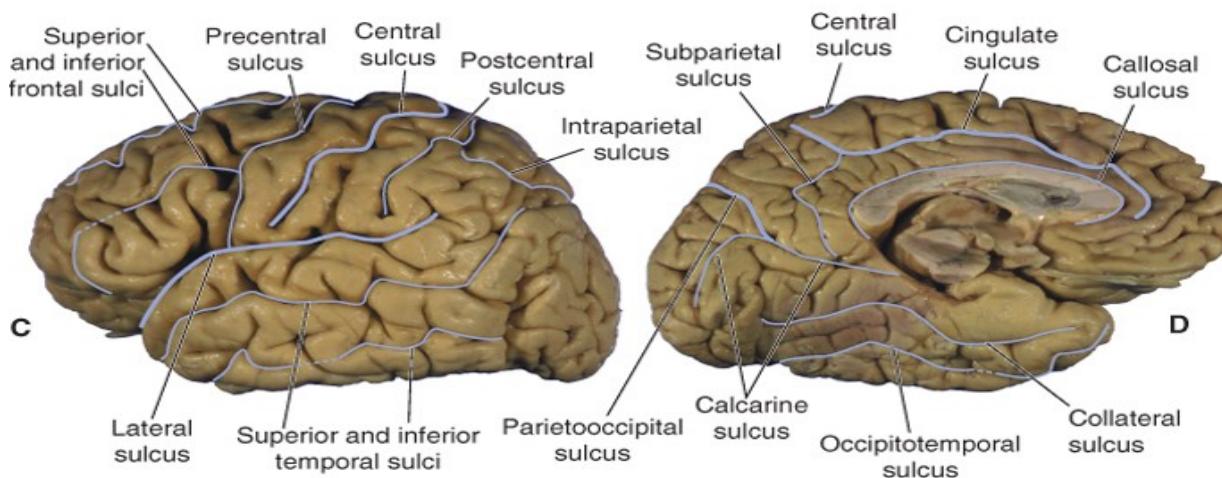


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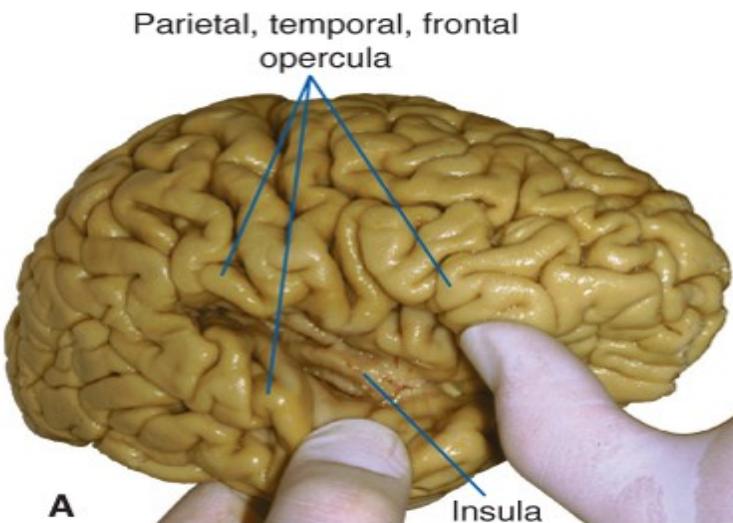


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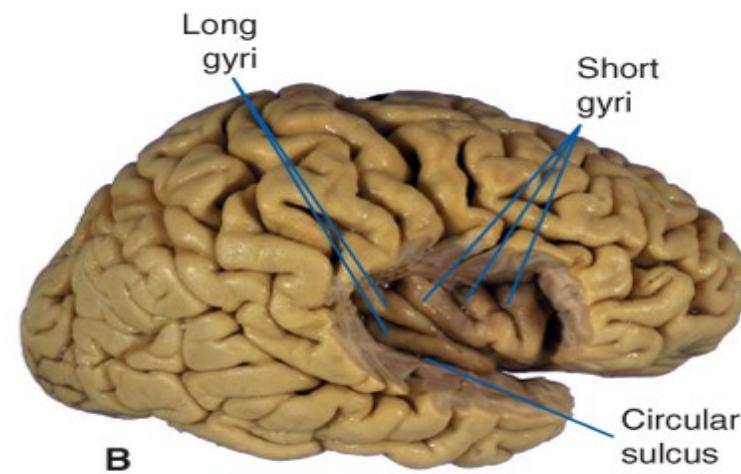
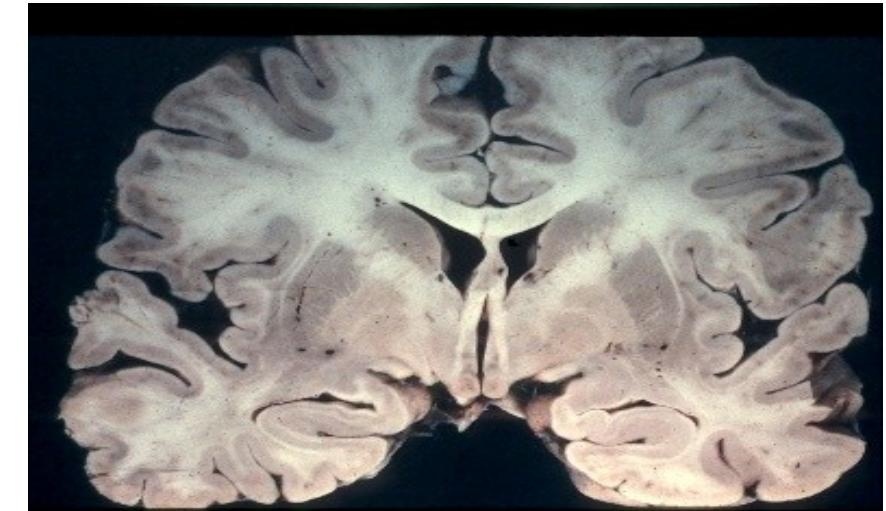
# Lobes of the Cerebral Hemispheres: The Insula



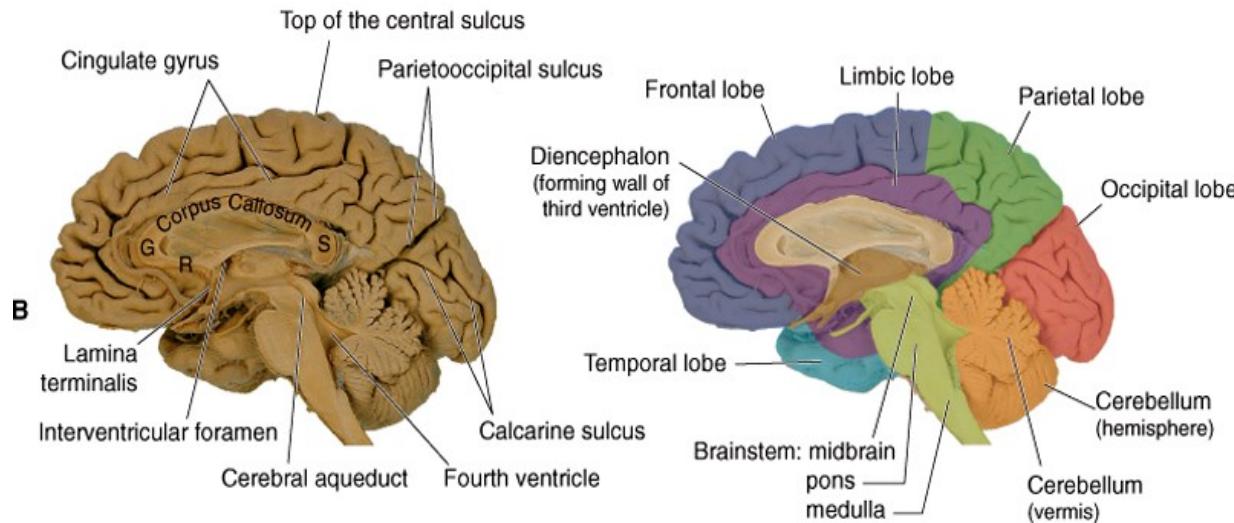
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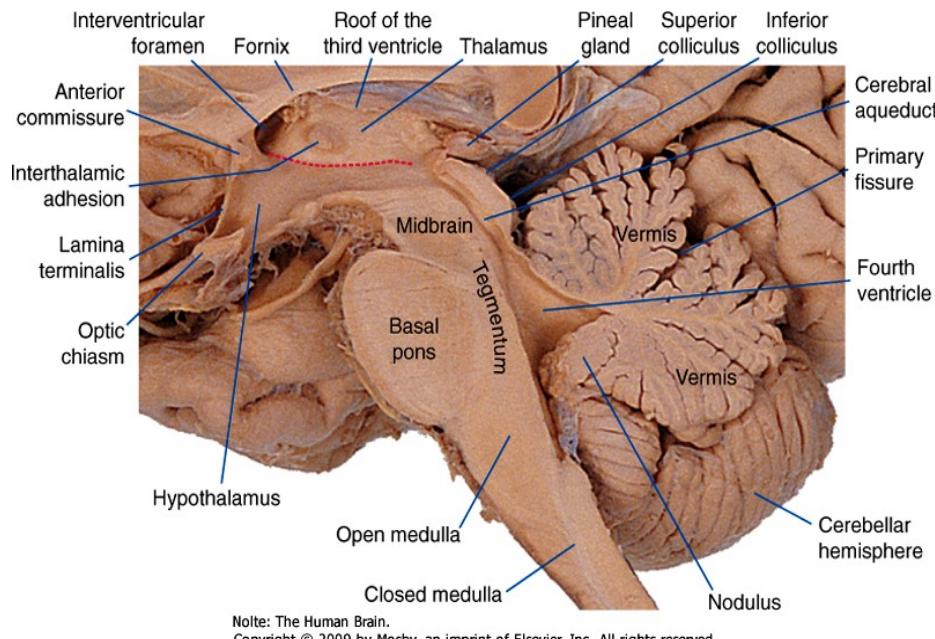
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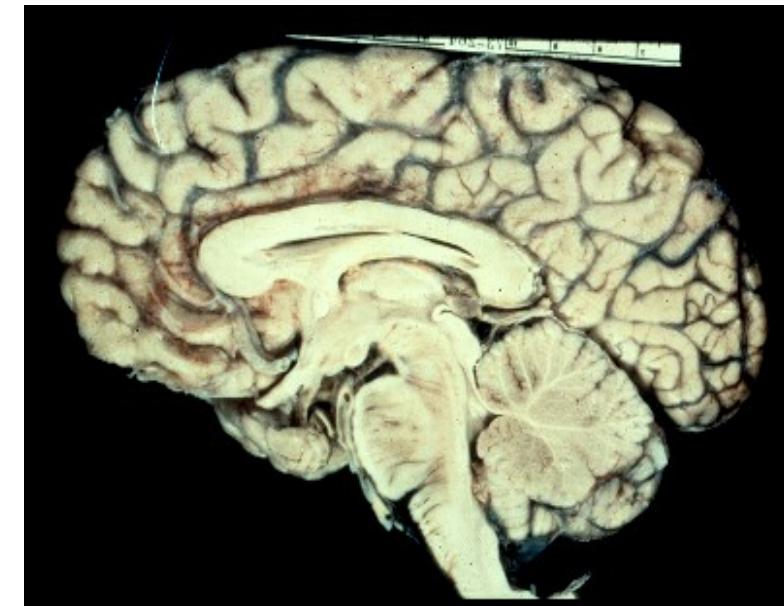
# Major Structures of the Brain: The Medial Aspect



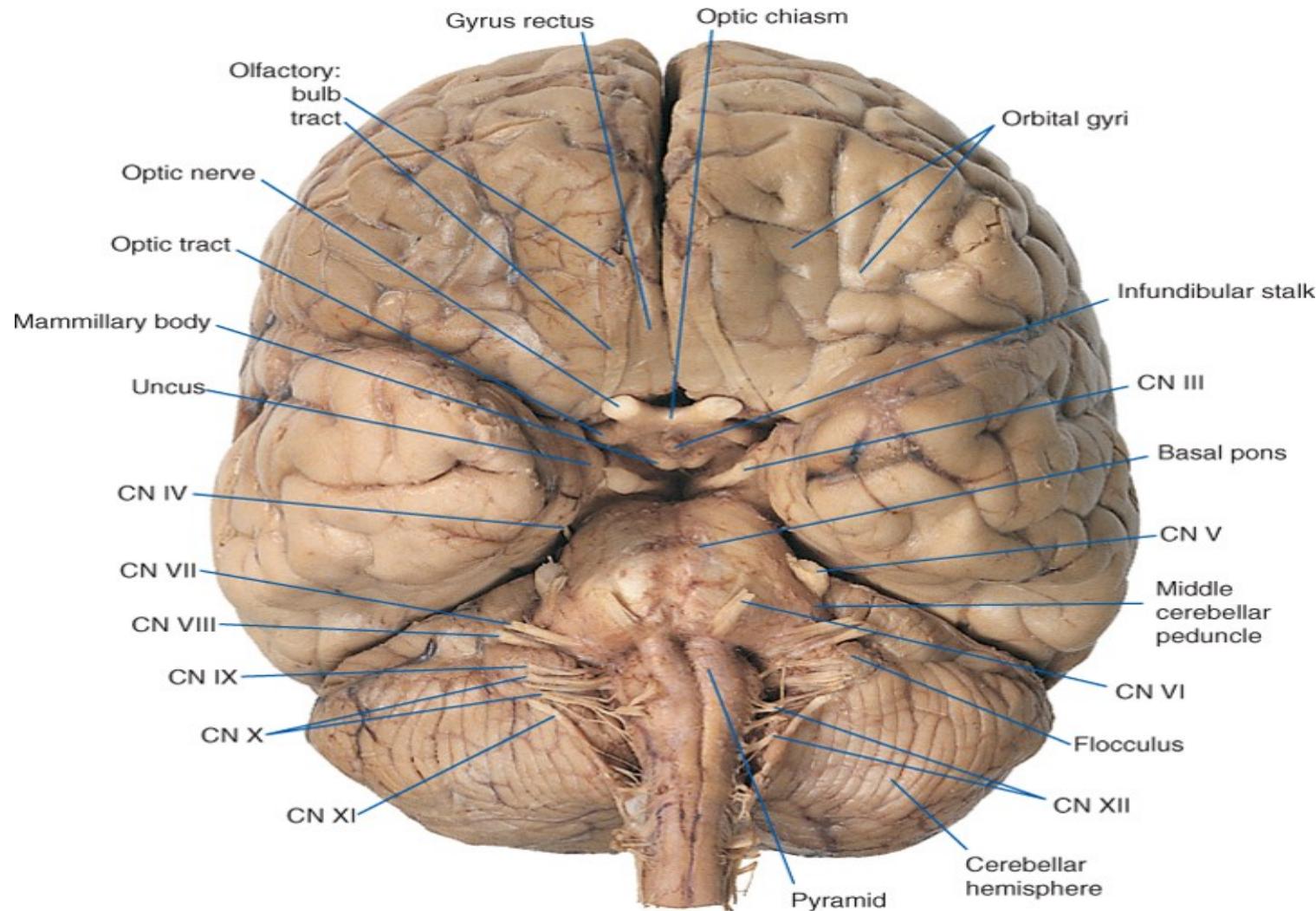
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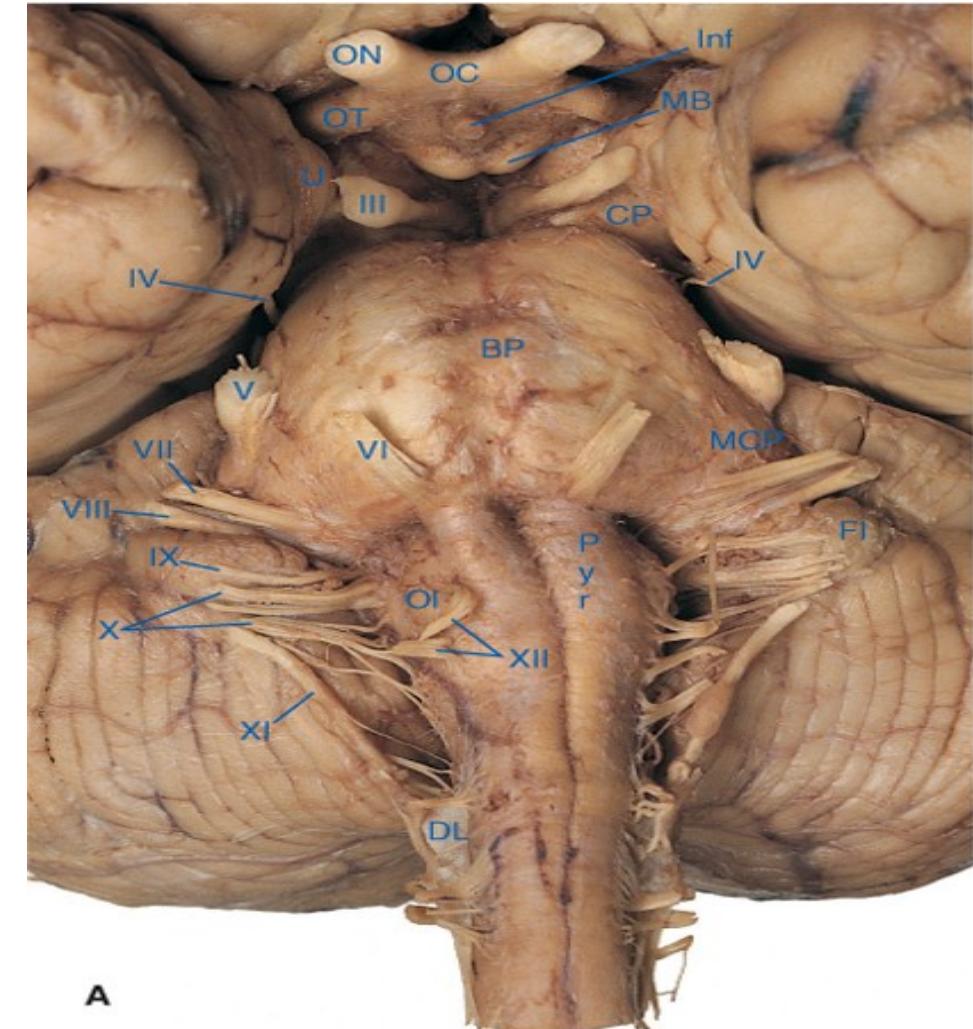
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# Major Structures of the Brain: The Ventral Aspect

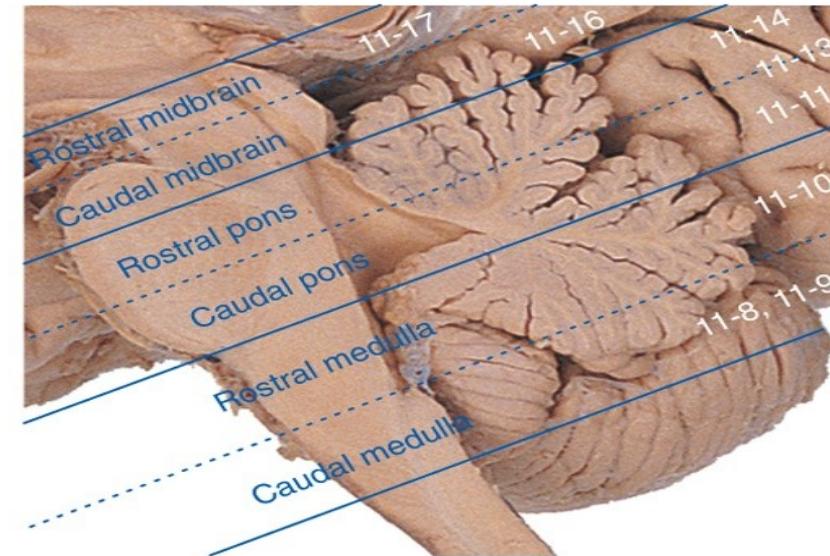
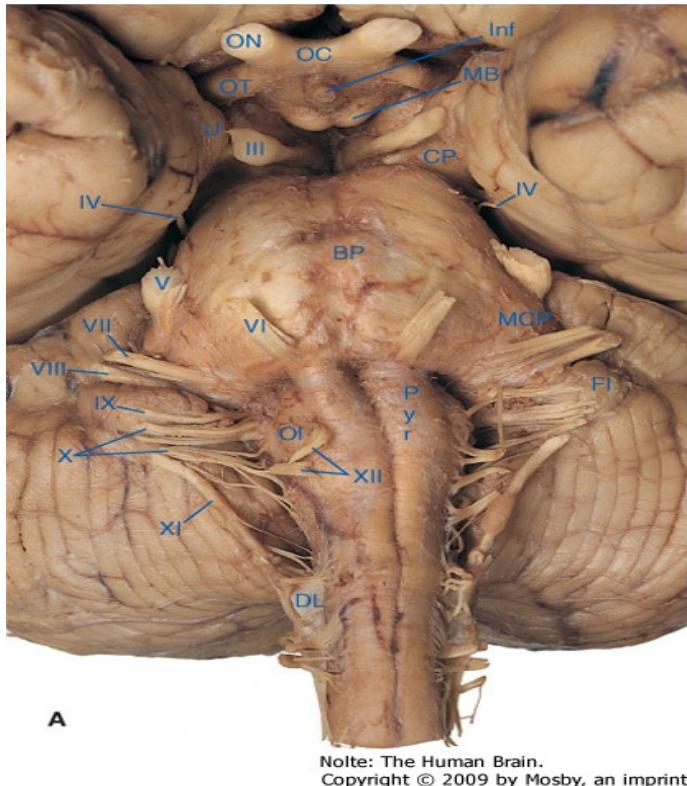


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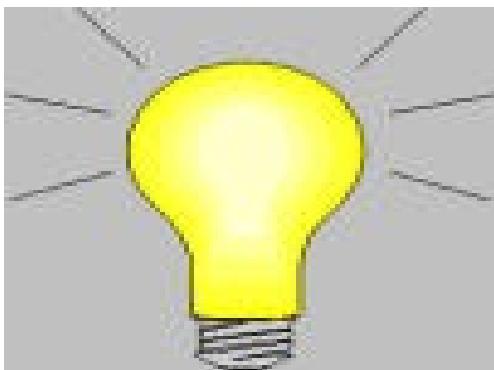
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# Organization of the Brainstem



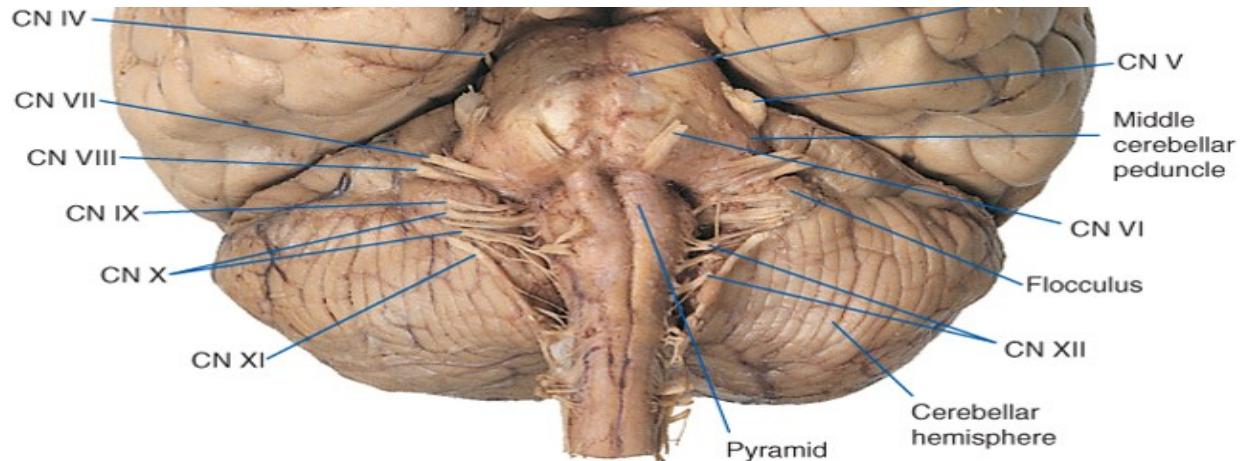
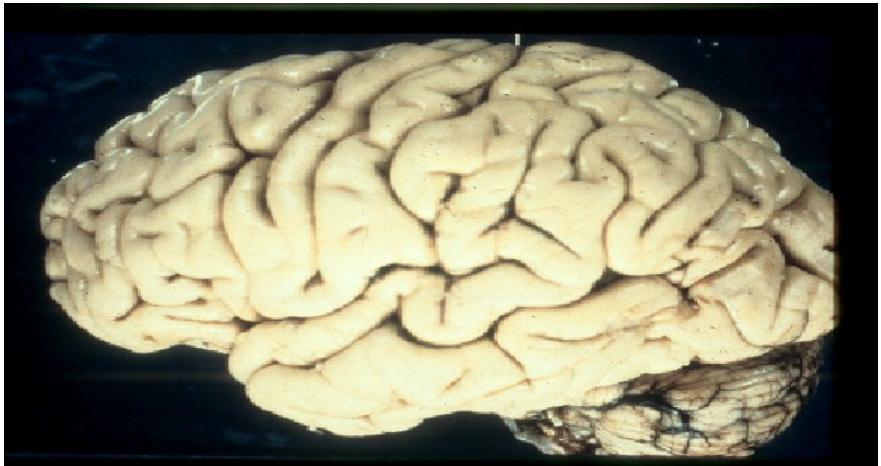
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- Composed of the medulla, pons and midbrain
- Also known as “the bulb” e.g. cortico-bulbar fibers

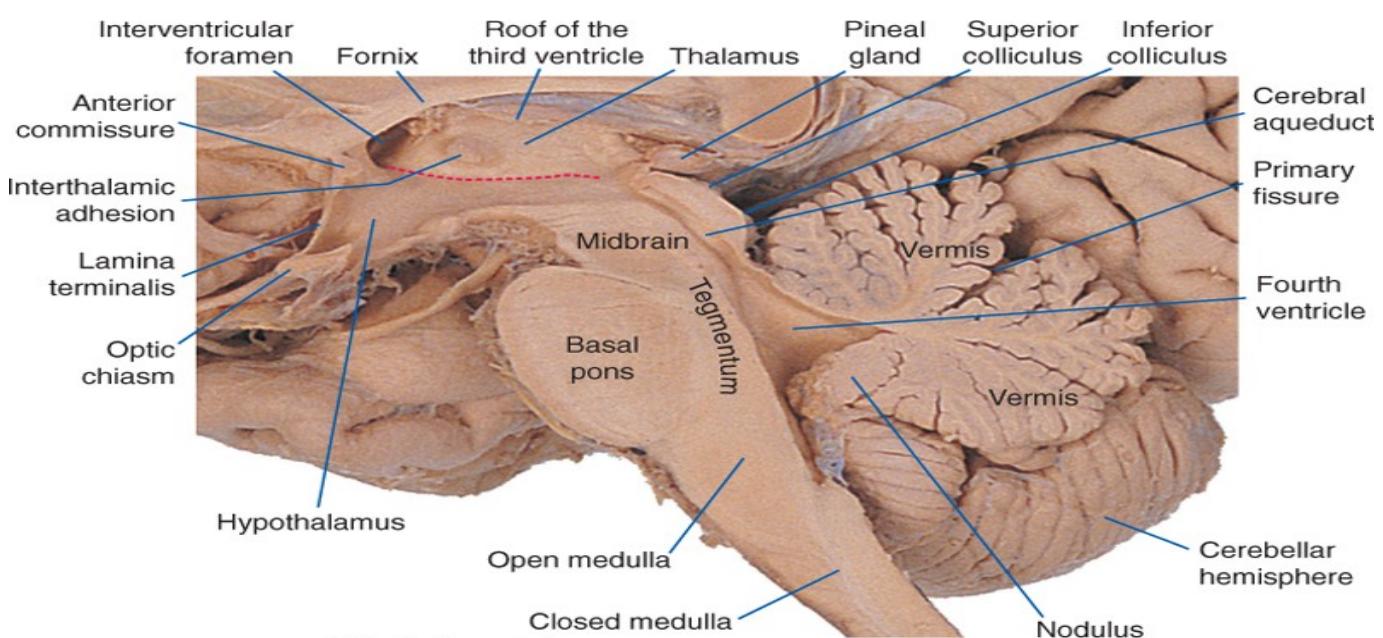


# Organization of the Cerebellum

- Composed of two hemispheres and a medial vermis
- Involved in motor coordination

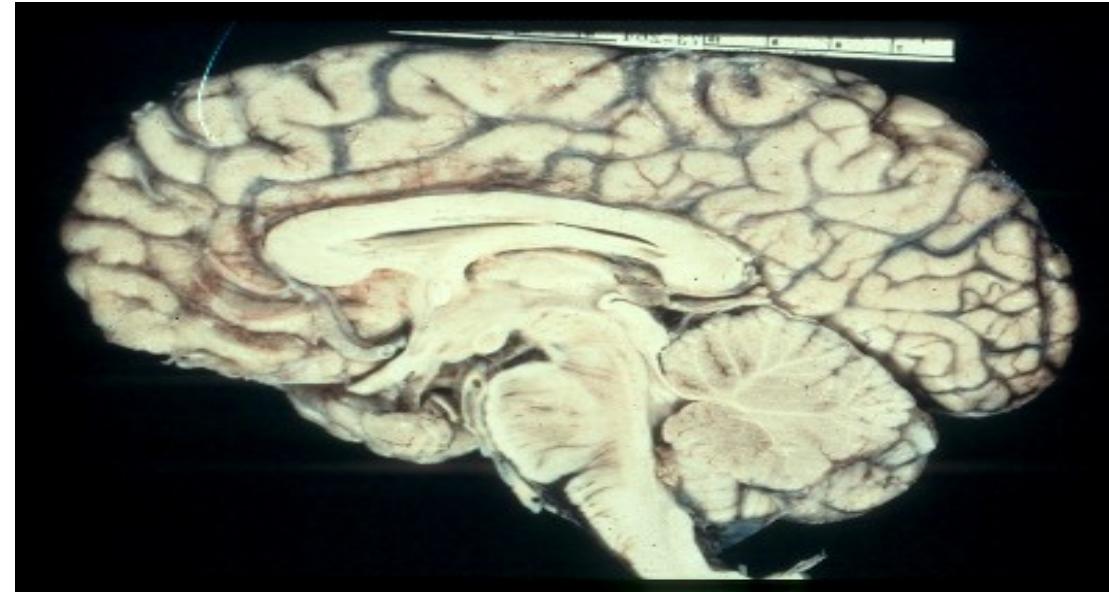
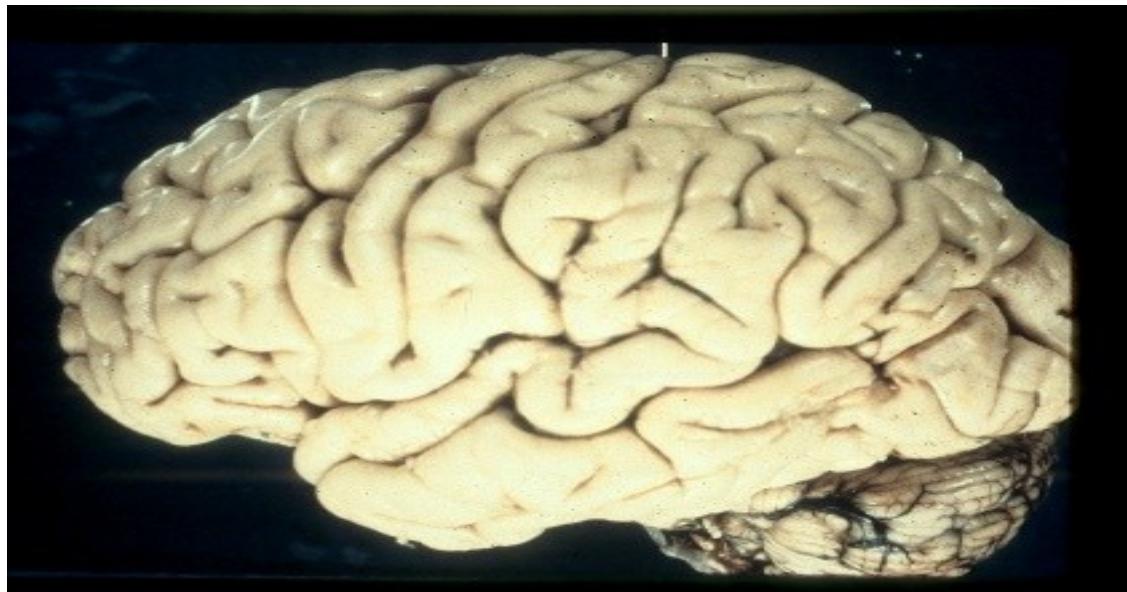


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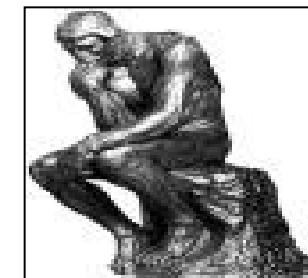
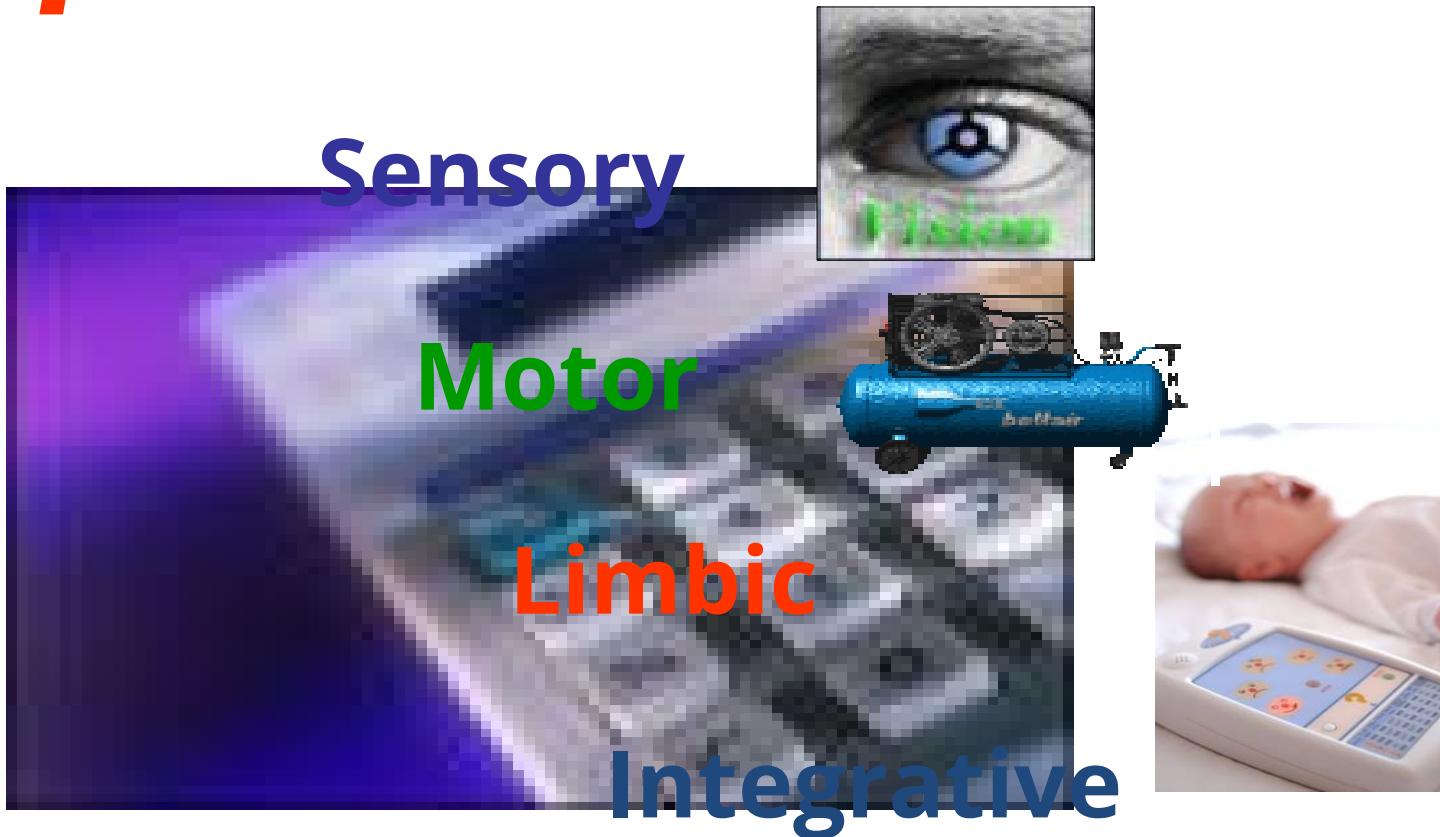
## Learning Tool: Developing a Three Dimensional Perspective



# 4

# Functional Divisions

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## Proprioception



## Vestibular

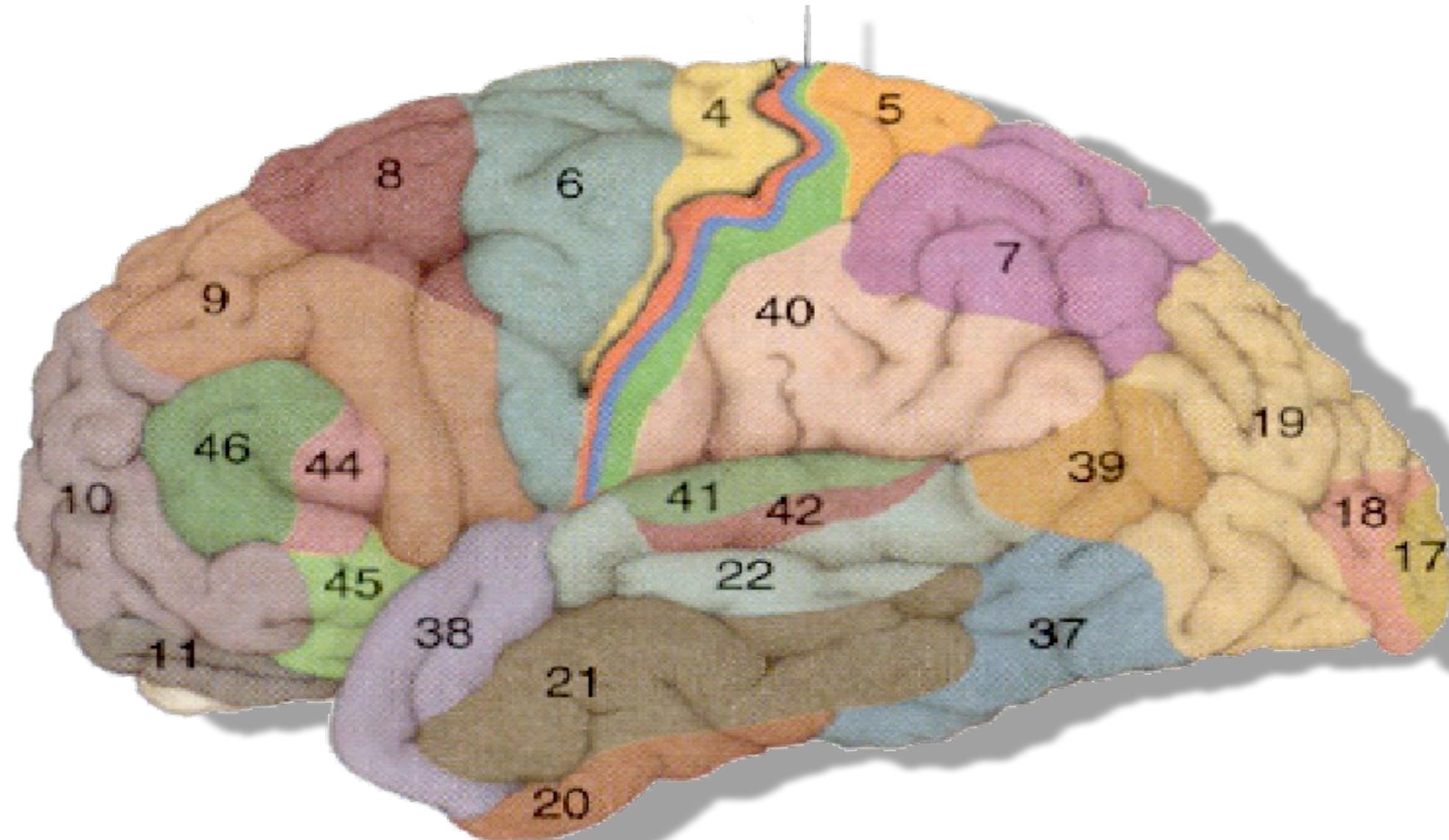


Senses



a taste





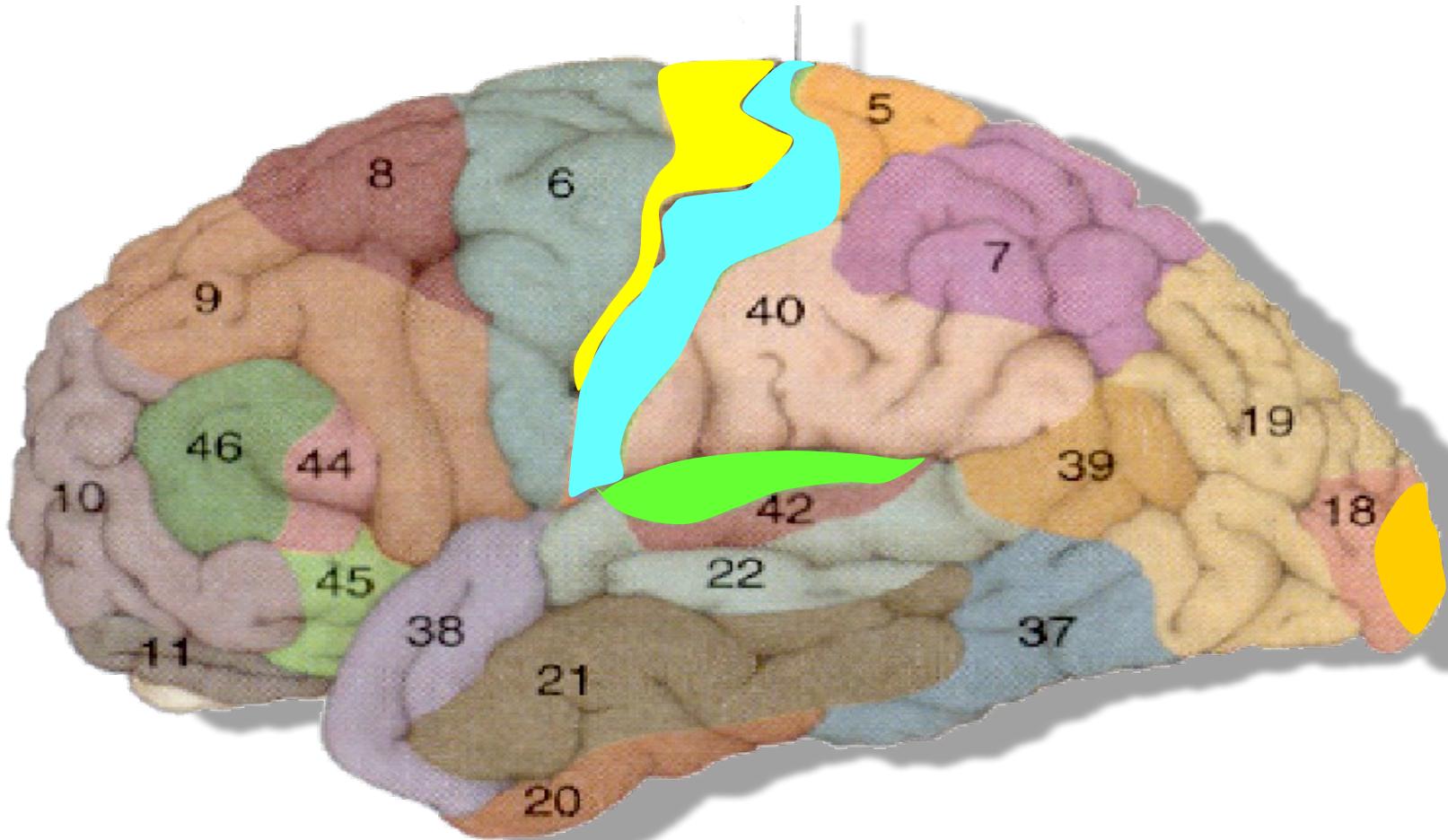
Brodmann Areas

# Primary versus Non-Primary Cortex

- **Primary cortex**
  - cortical areas that are the primary projection fields targeted by the sensory input pathways
  - and
  - cortical areas that are the principal fields which have neurons that project down into the spinal cord for motor control
  - Primary visual (Area 17, calcarine sulcus)
  - Primary auditory (Area 41, Heschl's)
  - Primary somatosensory (3,1,2, post-central gyrus)
  - Primary motor (4, pre-central gyrus)
- **Non-primary cortex**
  - everything in between
  - referred to collectively as **association cortex**

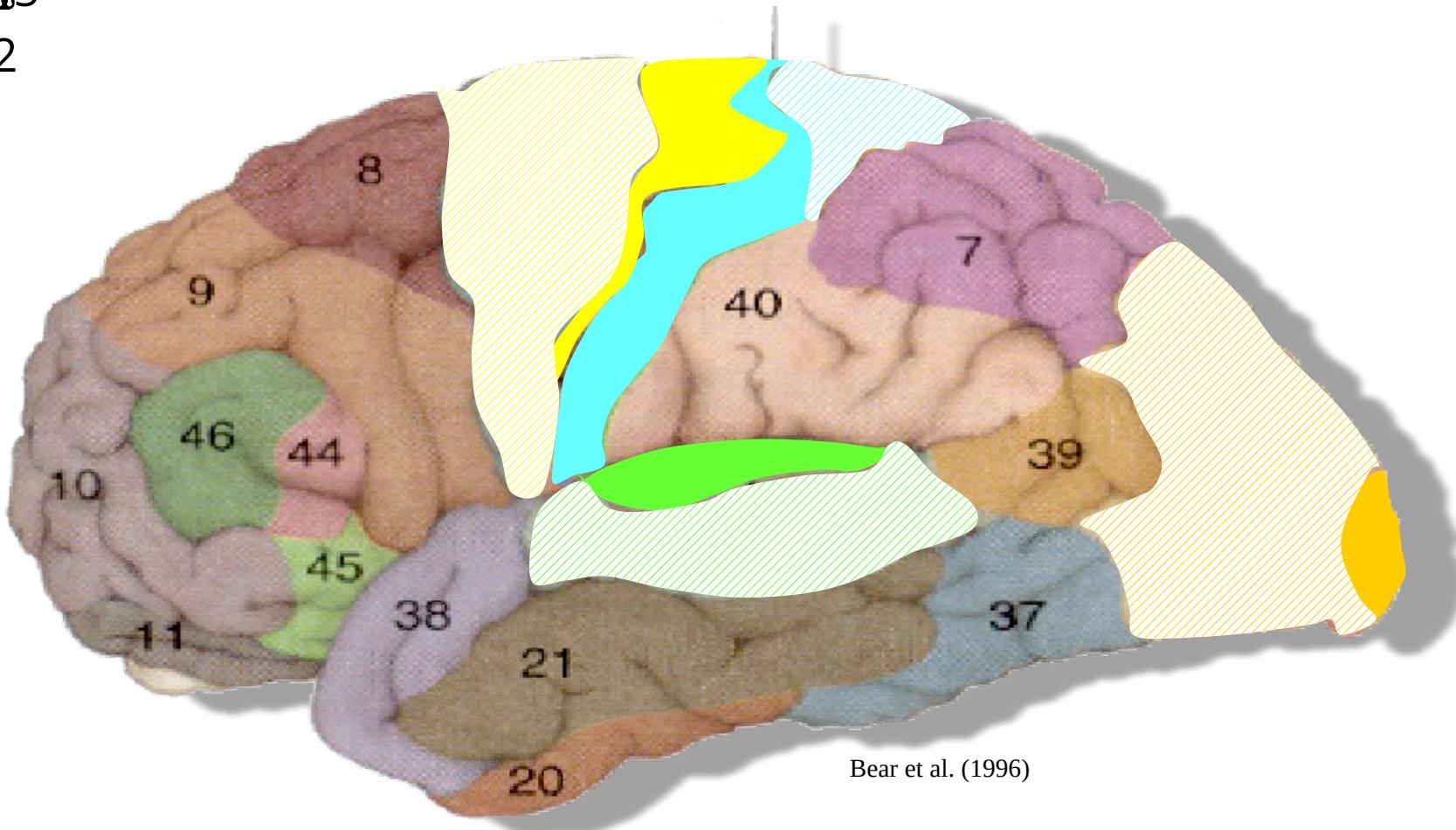
# Primary Areas

- 1° Somatosensory 3, 1, 2
  - 1° Auditory 41
  - 1° Visual 17
  - 1° Motor 4
  - Olfactory 27 piriform cortex
- 
- **Gustatory:**  
adjacent to 3a SI tongue projection
  - **Vestibular**  
not well defined in one region of the cortex

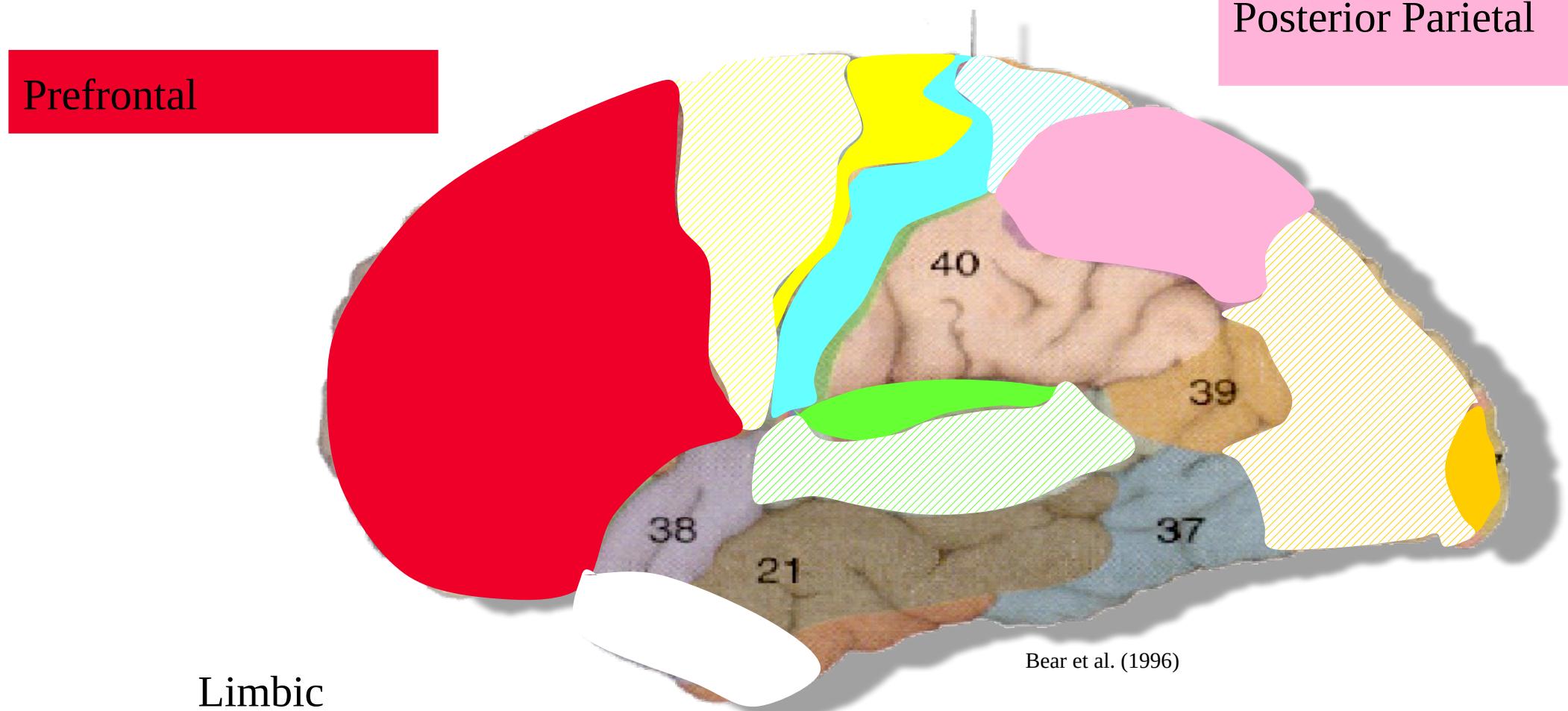


# Unimodal Association Areas (AA)

- Somatosensory ⚡5
- Auditory ⚡42 & 22
- Visual ⚡18 & 19
- PreMotor ⚡6



# Multimodal Association Areas

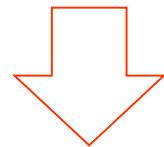


# Brodmann Areas

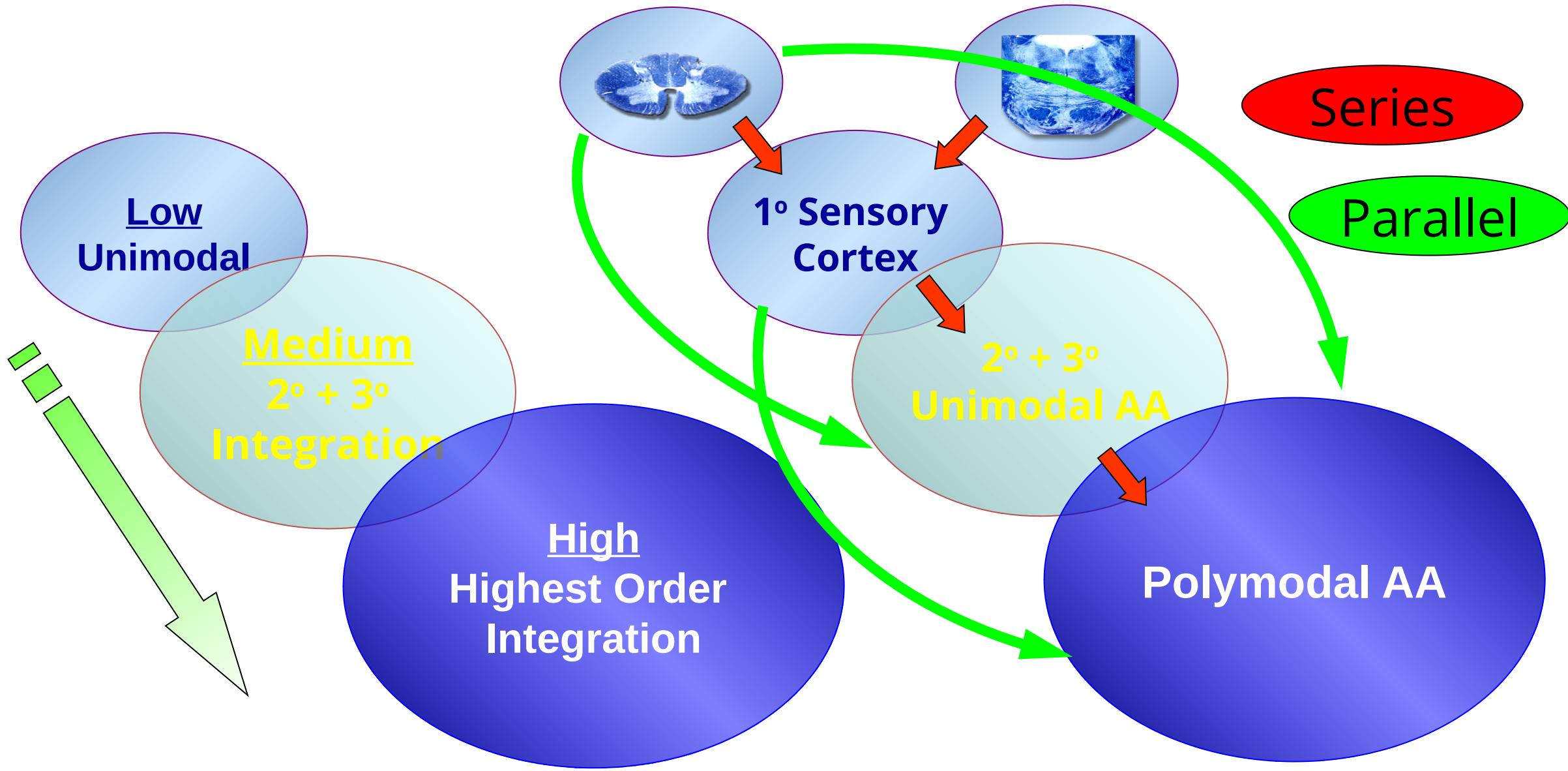
<u>Lobe</u>	<u>Area</u>	<u>Functional Name</u>	<u>Location</u>
Frontal	4	1° Motor Cortex	Precentral Gyrus & Anterior Paracentral Lobule
	6	Premotor & Supplemental Motor Cortices	Superior & Middle Frontal Gyri; Precentral Gyrus
	8	Frontal Eye Fields	Superior & Middle Frontal Gyri
	44 & 45	Broca's Area	Opercular & Triangular parts of Inferior Frontal Gyrus
	9 - 12	Prefrontal Cortex	Anterior half of Frontal Cortex
Parietal	3, 1, 2		<del>Postcentral Gyrus &amp; Posterior Paracentral Lobule</del>
	5	1° Somatosensory Cortex	Posterior Wall of Postcentral Sulcus
	7	Somatosensory Unimodal Association Area Somatosensory Multimodal Association Area	Superior Parietal Lobule
Occipital	17	1° Visual Cortex	Cortical Banks of Calcarine Sulcus
	18, 19	Visual Association Area	Occipital Cortex surrounding area 17
Temporal	41	1° Auditory Area	Superior Temporal Gyrus <del>&amp;</del> Transverse Temporal Gyri (of Heschl)
	42, 22	Auditory Association Area	Superior Temporal Gyrus - posterior portion of 22 = Wernicke's Area

## Cortical **Sensory** Hierarchy

Simple **Sensory**



Complex **Sensory**



## Cortical Sensory Hierarchy

# Sensory Cortex Somatotopy are Activity Dependent

Plastic



Syndactyly



Phantom Limb Sensation

# Food Handling in the Raccoon



# Syndactyly

- The failure of differentiation in which the fingers fail to separate into individual appendages. This separation usually occurs during the 6th and 8th weeks of embryologic development.
- The root words of the term syndactyly are derived from Greek; *syn* means together, and *dactyly* means fingers or digits.

# Somatotopic Digit ReMapping in SI

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P. ZARZECKI ET AL.

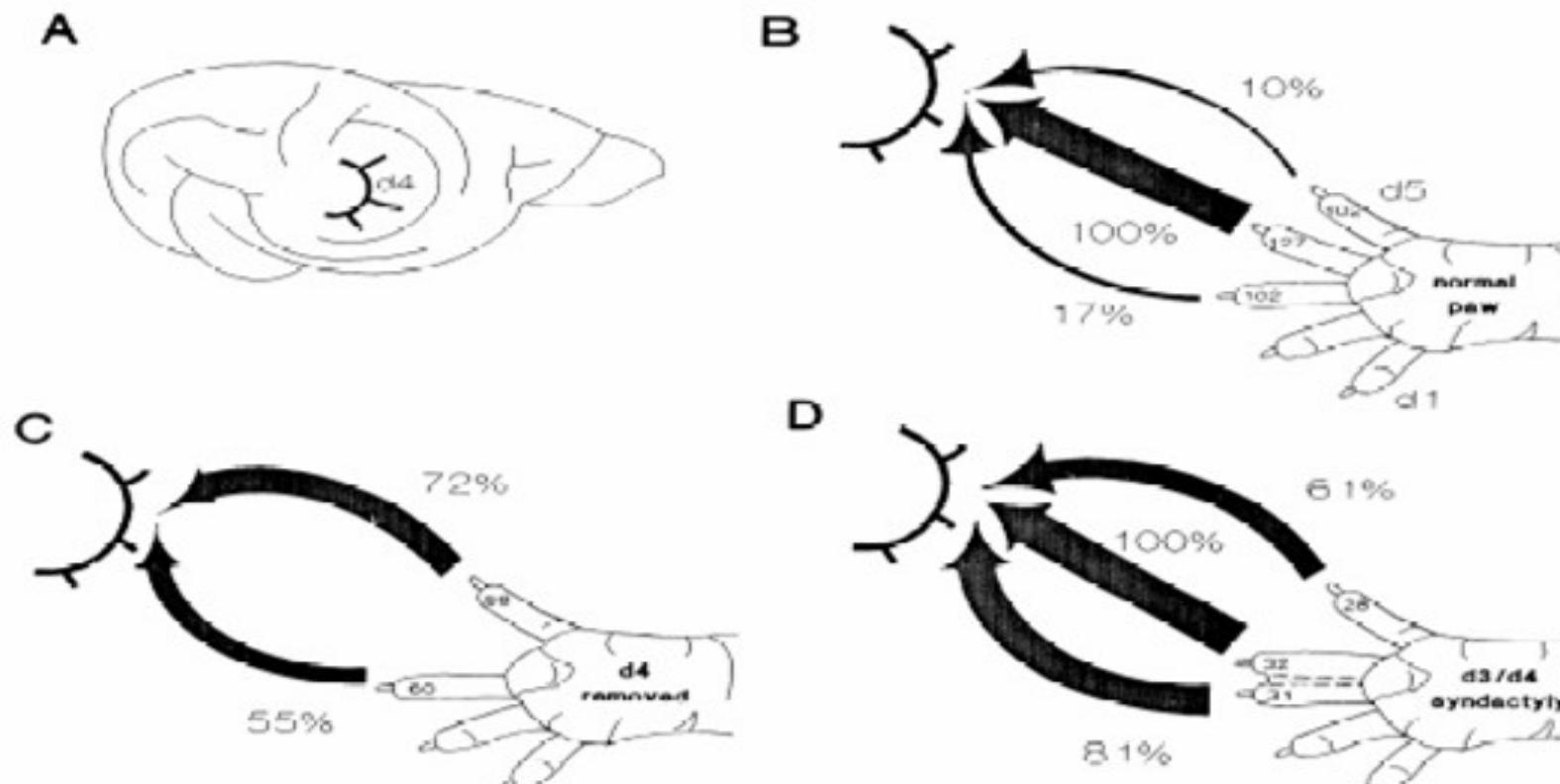
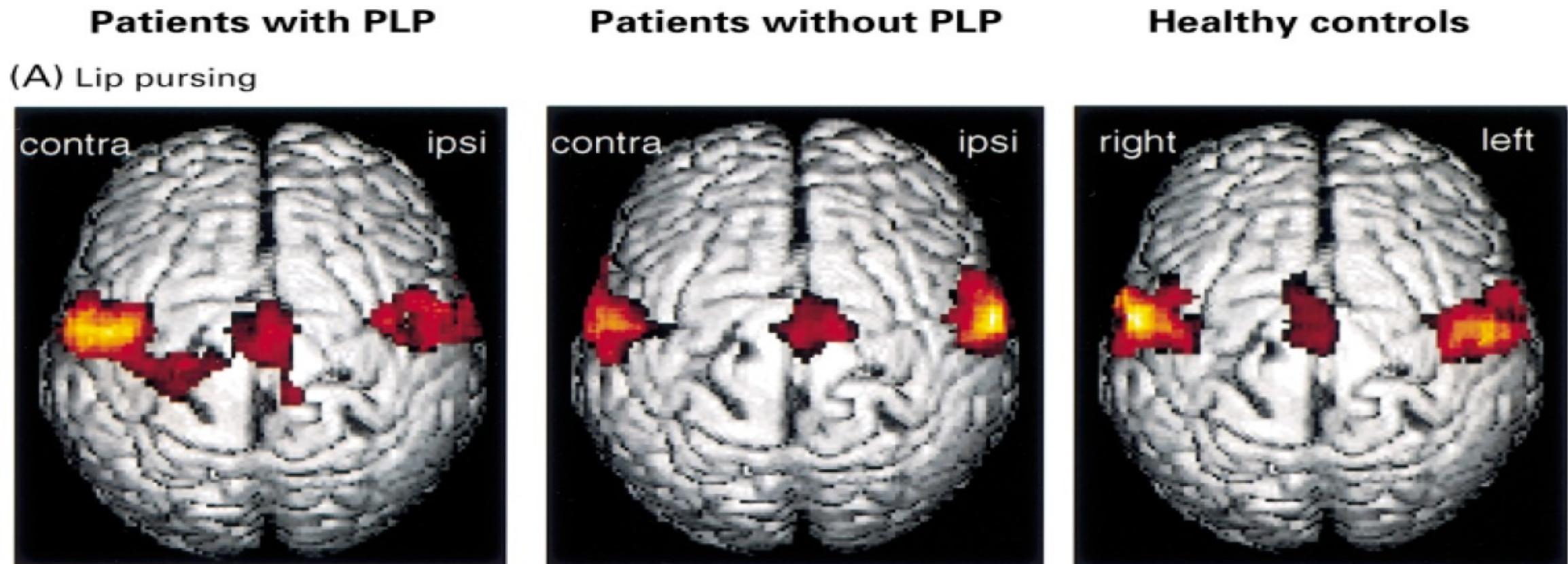


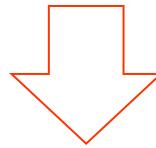
FIG. 2. Summary of the proportions of neurons with somatosensory excitatory postsynaptic potentials (EPSPs) evoked by stimulation of digit 3 (d3), digit 4 (d4), and digit 5 (d5) in the 3 groups of raccoons. Numbers on digits: numbers of neurons tested for responses from that digit. The widths of the arrows are weighted according to the proportion of neurons affected from each digit. *A*, all neurons were recorded in the d4 subgyrus of primary somatosensory cortex. *B*, in control animals with normal paws, only a minority of neurons had EPSPs in response to stimulation of the off-focus digits (d3 and d5). *C*, after d4 was removed, the proportion of neurons with somatosensory inputs from d3 or d5 increased dramatically. *D*, in raccoons with d3 and d4 fused together, the off-focus digits (d3 and d5) became major sources of somatosensory input.

# Phantom Limb Pain (PLP) and S1



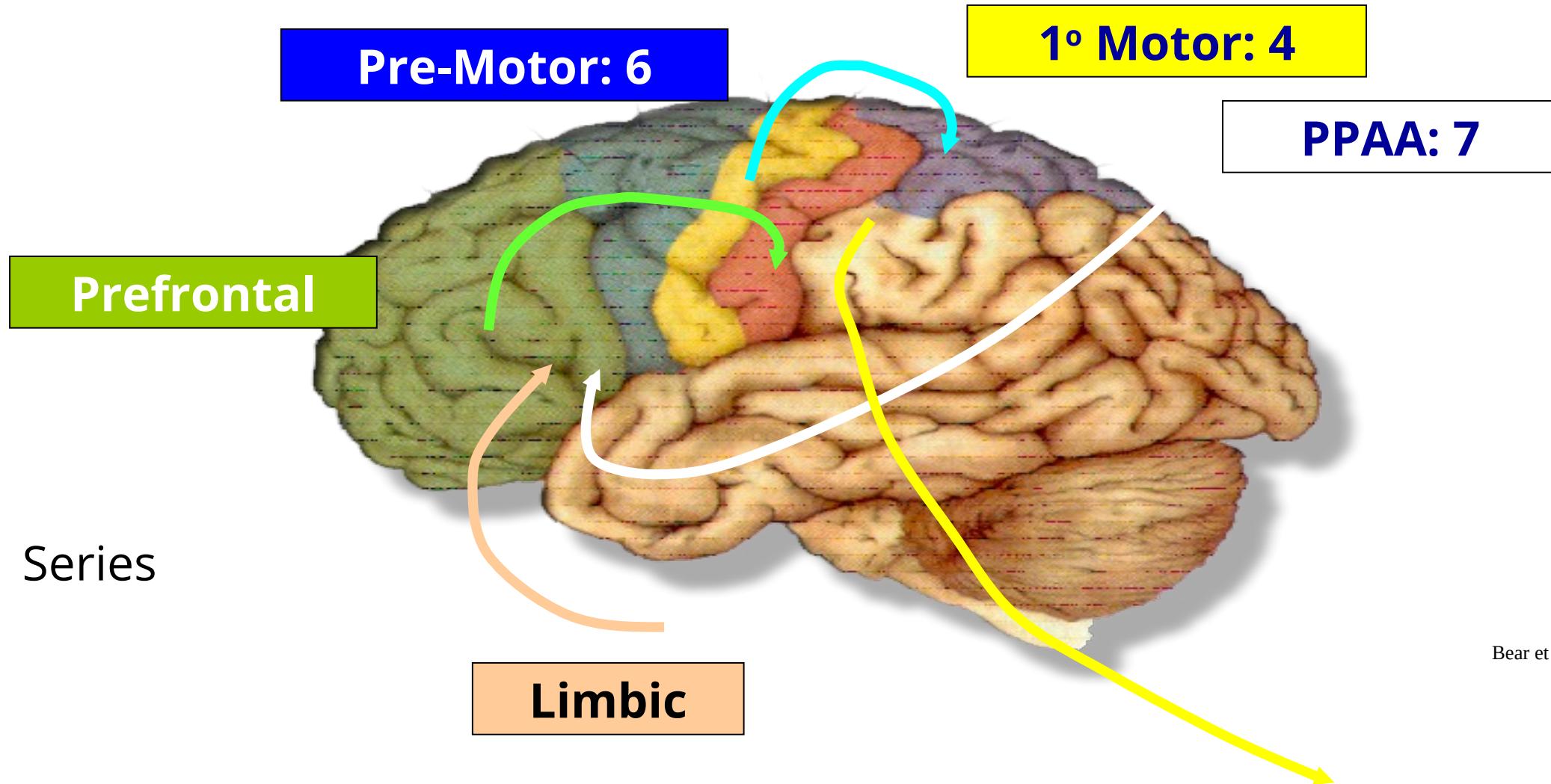
# **Cortical Motor Hierarchy**

**Complex Motor**



**Simple Motor**

# Cortical Motor Hierarchy

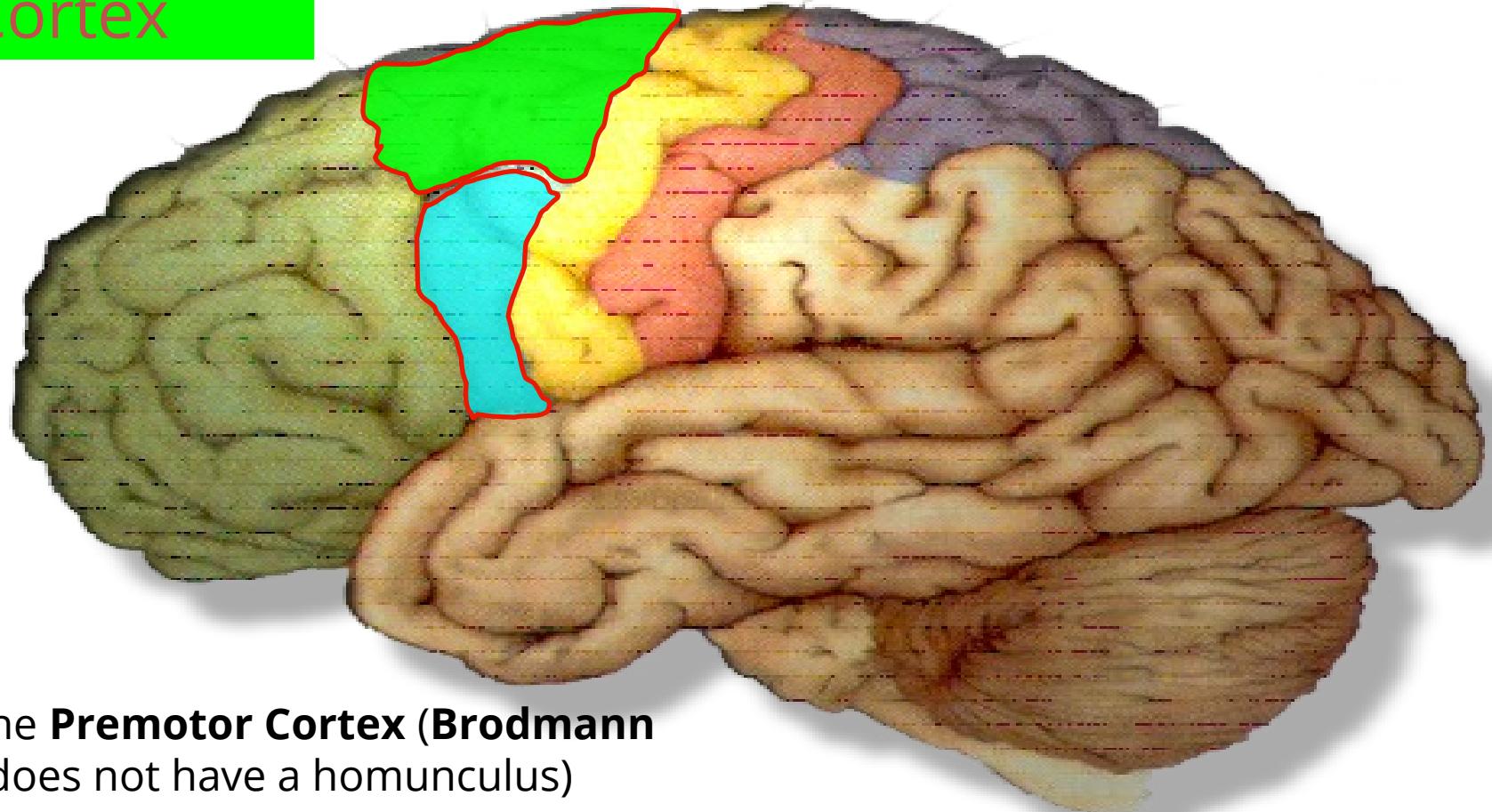


Bear et al. (1996)

## Pre-Motor Area Area 6

Supplementary  
Motor Cortex

Pre-Motor  
Cortex

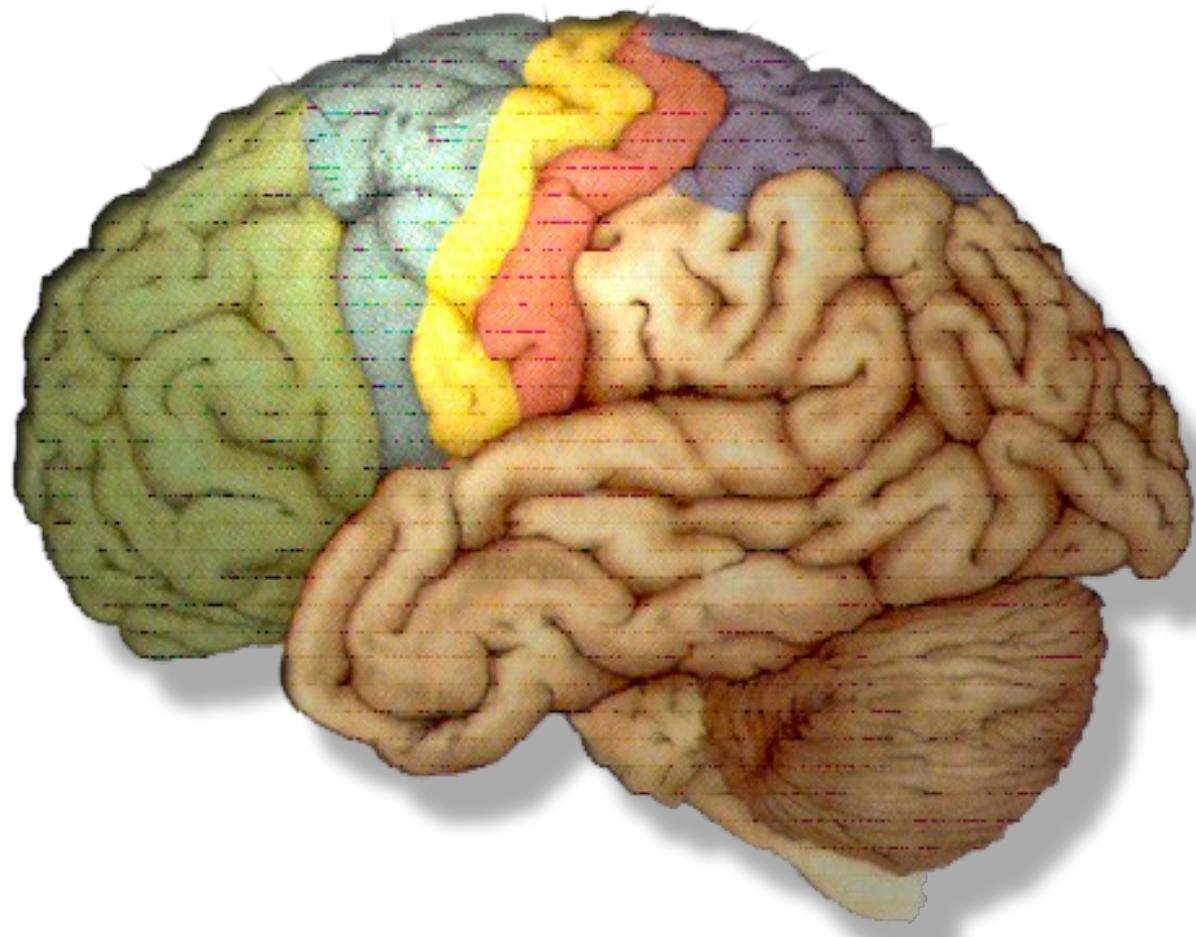


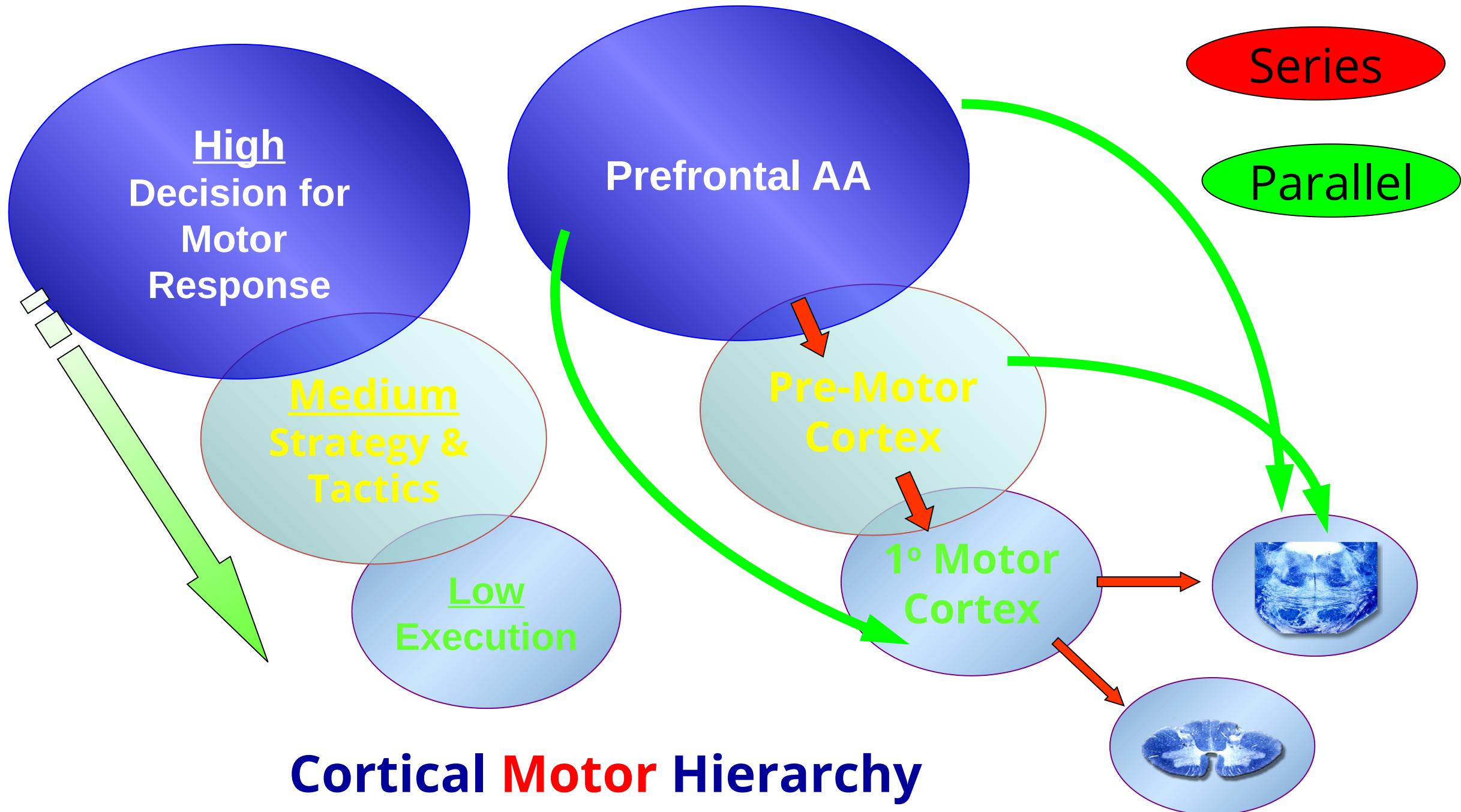
Posterior to PFAA is the **Premotor Cortex (Brodmann Area 6)**. (This region does not have a homunculus)

## 1<sup>o</sup> Motor Cortex (M1)

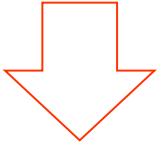
Area 4

The primary MOTOR CORTEX is found in a gyrus just anterior to the central sulcus. The motor cortex is also known as **Brodmann Area 4**.

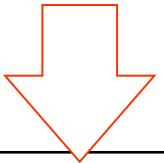




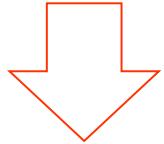
Simple **Sensory**



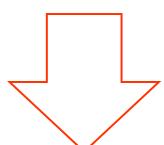
Complex **Sensory**



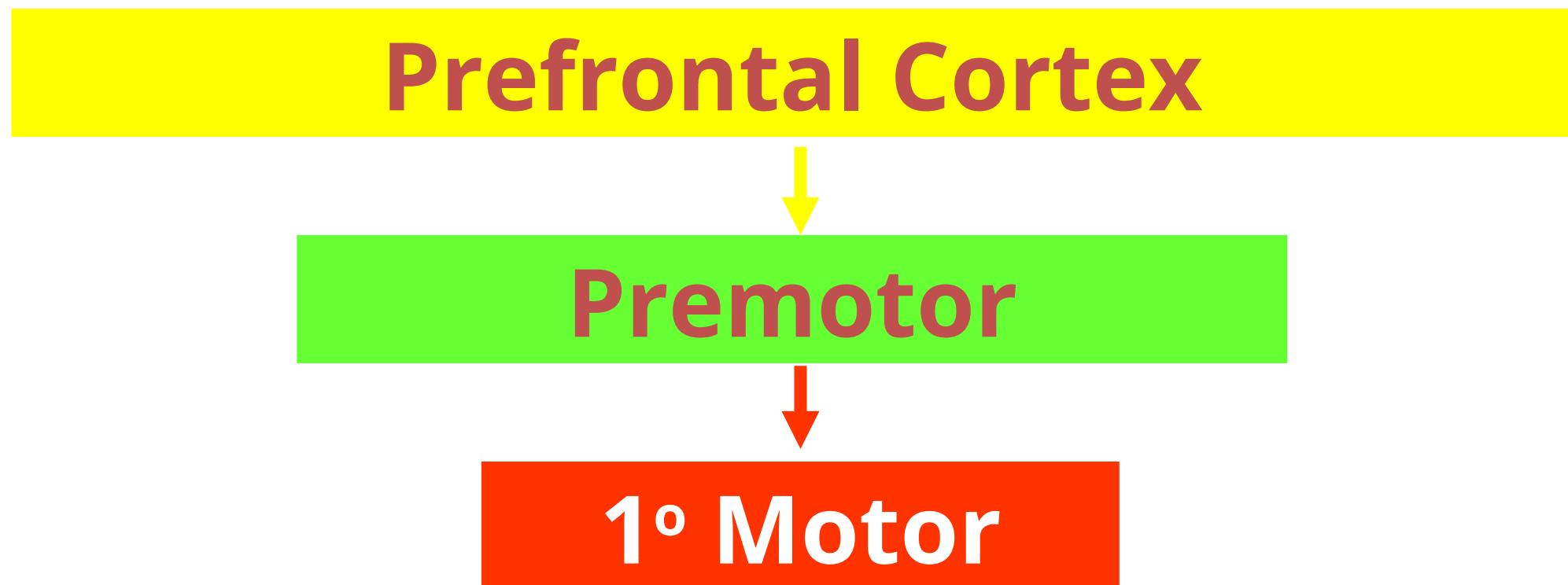
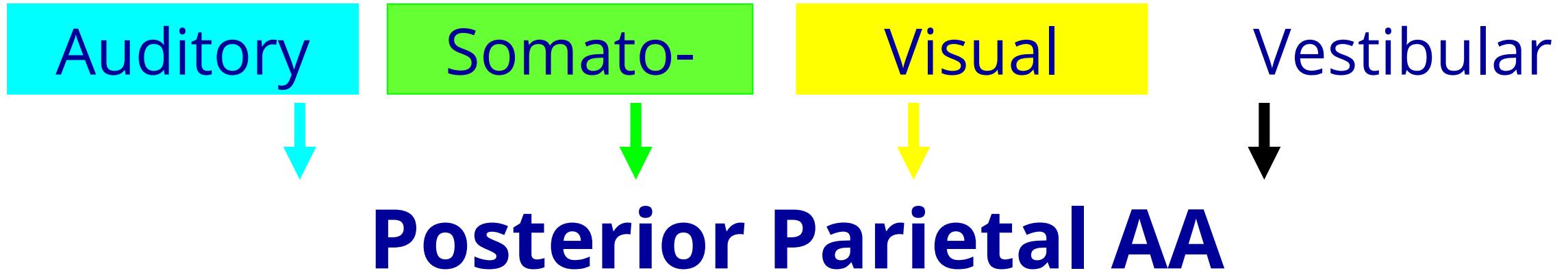
Integration



Complex **Motor**



Simple **Motor**



# Concepts to re-familiarize yourself with for future classes

- Transcription
- Translation
- Phosphorylation
- Cellular energy requirements
- Organelles w/ in a cell

Thanks for listening and I look forward  
to working with you!!