

M U N I

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**2**

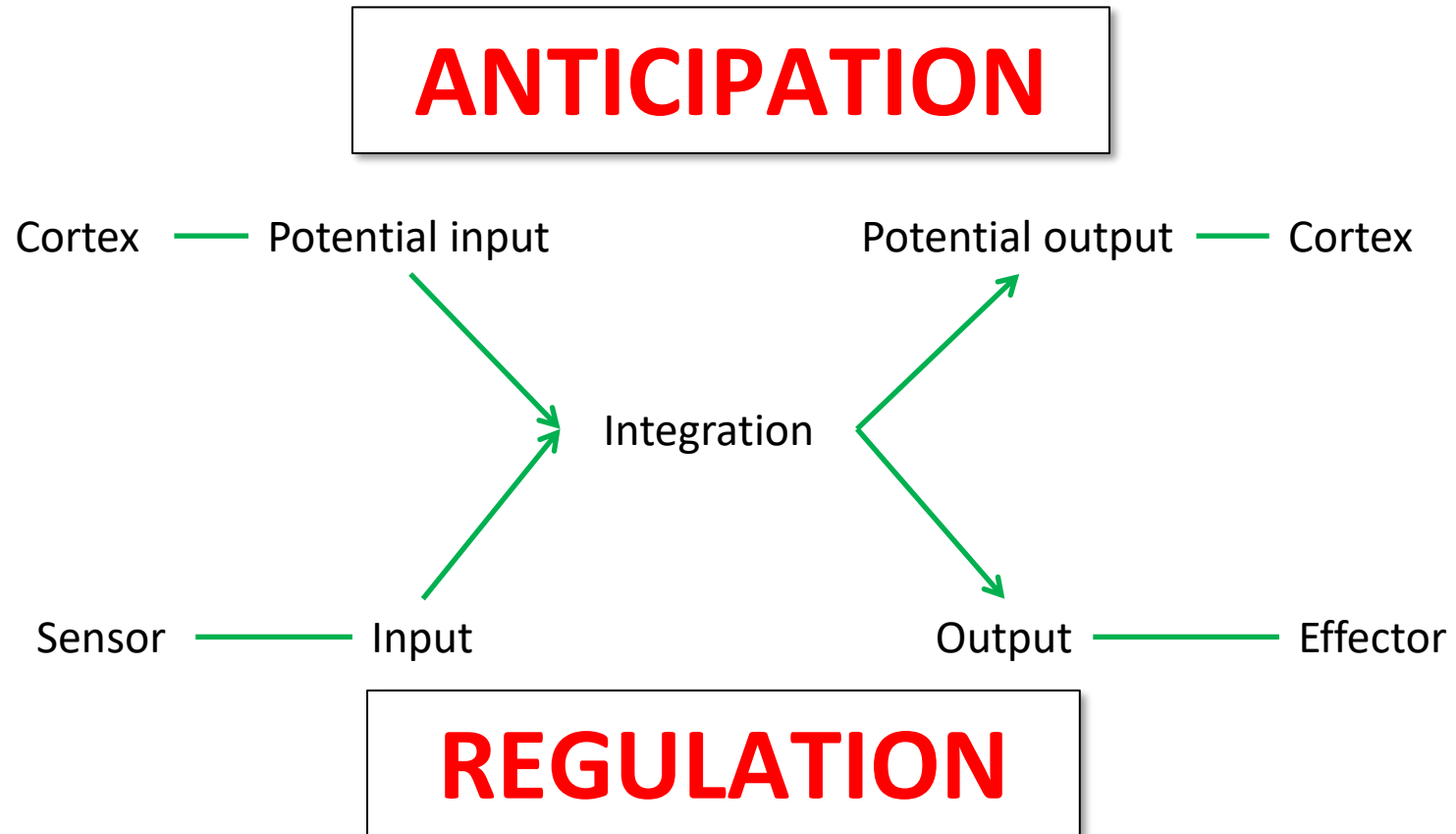
# **The hierarchy and the logic of nervous system evolution**

# Evolutionary approach

## Evolution is not revolution



# The role of nervous system



# The logic of evolution of the nervous system

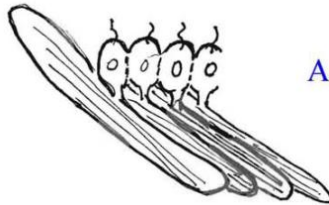
Input → Integration → Output

## Four basic types of tissue

- ✓ Epithelial
- ✓ Connective
- ✓ Muscular
- ✓ Nervous

# The logic of evolution of the nervous system

Input → Integration → Output



A. Myoepithelium:  
contractile epithelial cells  
responding to stimulation and  
interconnected by electrical  
synapses (gap junctions)

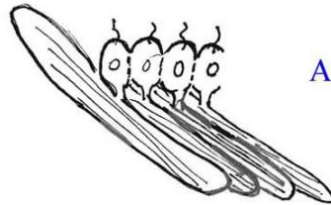
Gerald Schneider. *9.14 Brain Structure and Its Origins, Spring 2014*. (Massachusetts Institute of Technology: MIT OpenCourseWare), <http://ocw.mit.edu> (Accessed). License:Creative Commons BY-NC-SA

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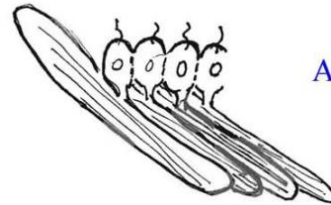


B. Protomyocytes separate  
from sensory epithelium,  
all connected by electrical  
synapses

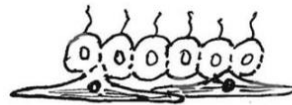
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# The logic of evolution of the nervous system

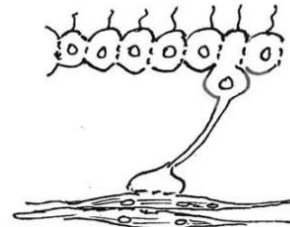
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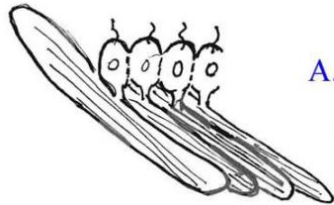
C. Protoneurons appear,  
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# The logic of evolution of the nervous system

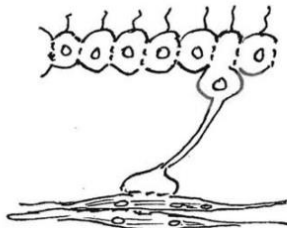
Input → Integration → Output



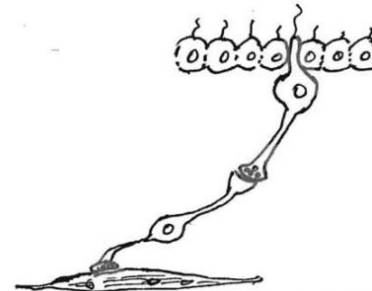
A. Myoepithelium: contractile epithelial cells responding to stimulation and interconnected by electrical synapses (gap junctions)



B. Protomyocytes separate from sensory epithelium, all connected by electrical synapses



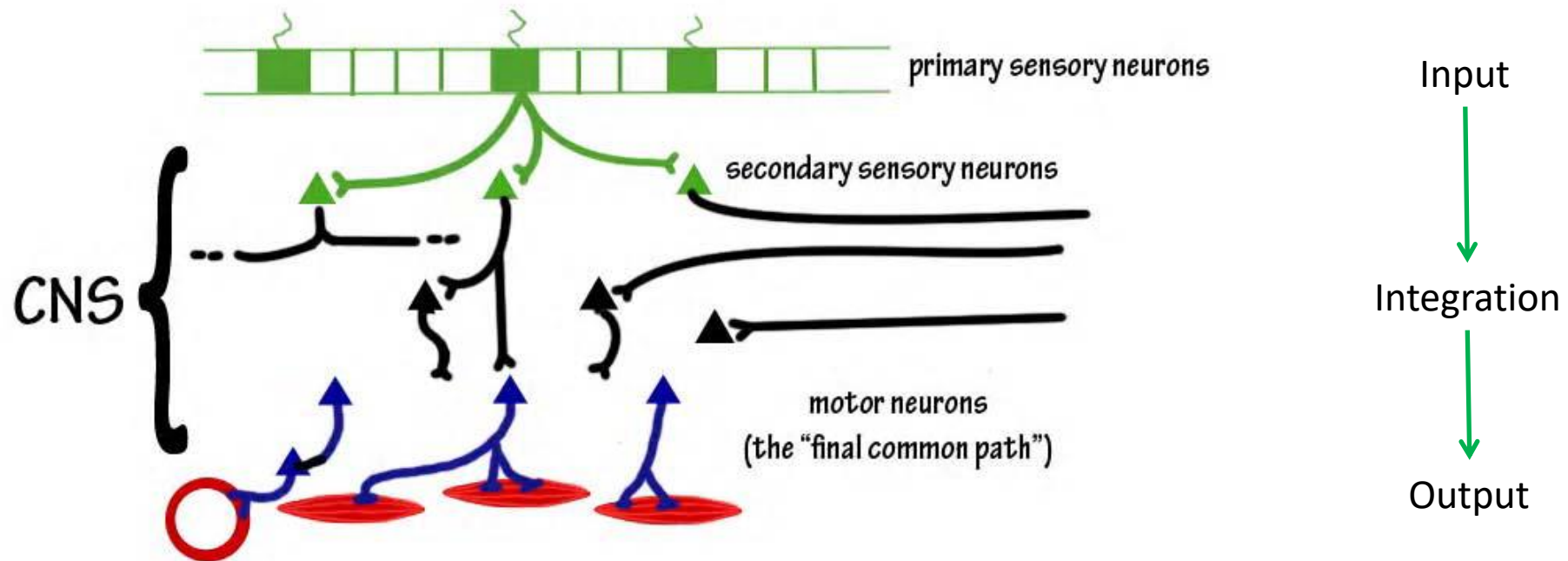
C. Protoneurons appear, sensory and connected to separate contractile cells



D. Neurons appear, separate from both neurosensory cells and contractile cells. Chemical synapses appear.

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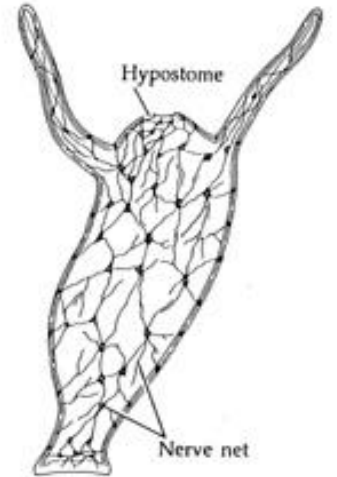
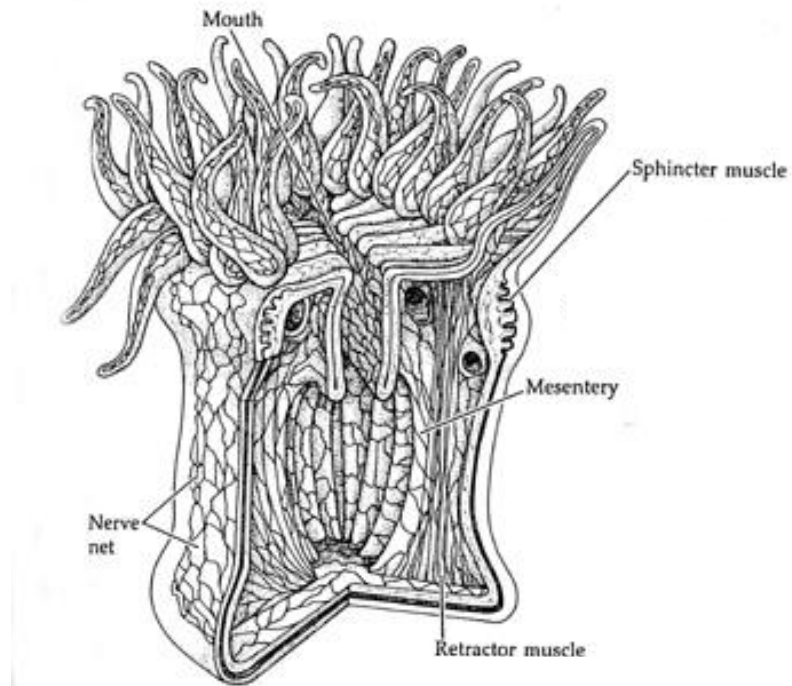
# The logic of evolution of the nervous system



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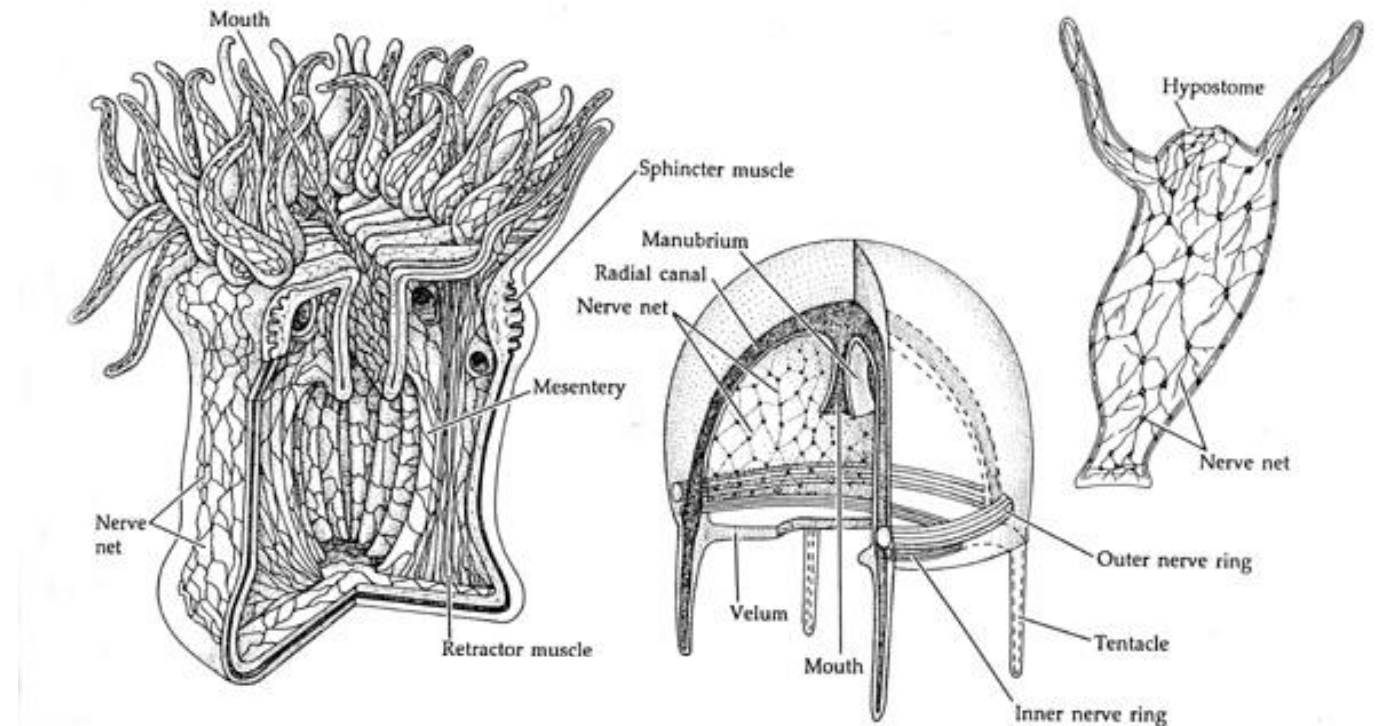
# The logic of evolution of the nervous system

- Polyp
  - Reticular NS
  - Nonspecific reaction on irritation



# The logic of evolution of the nervous system

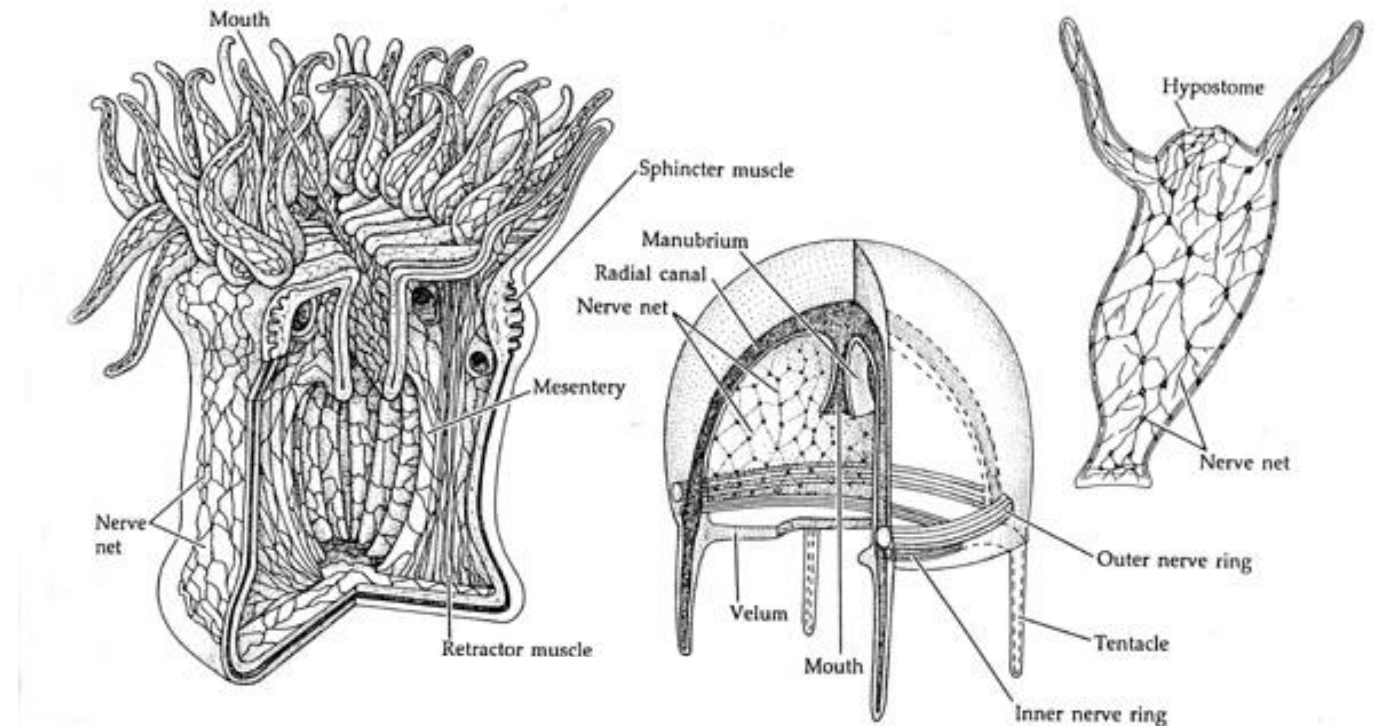
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- Jellyfish
  - Around propulsion part is nervous system into the ring
  - Coordinated contraction – coordinated movement



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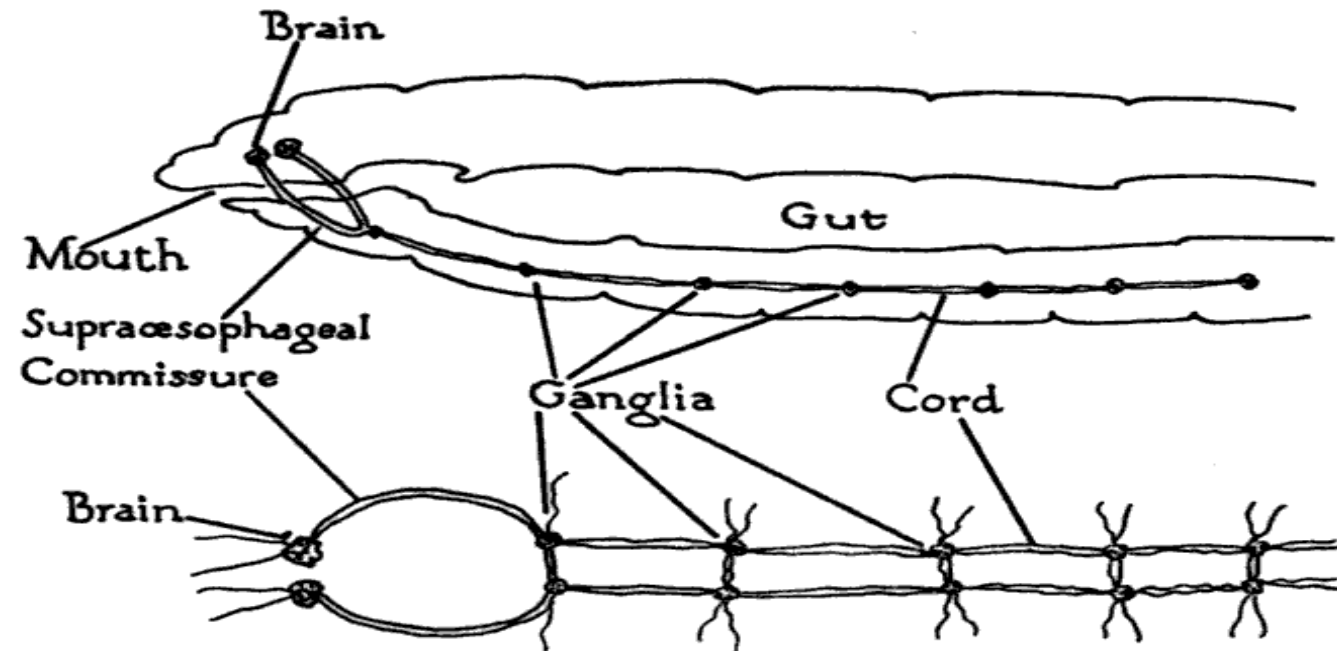
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**FOTORECEPTION**



# The logic of evolution of the nervous system

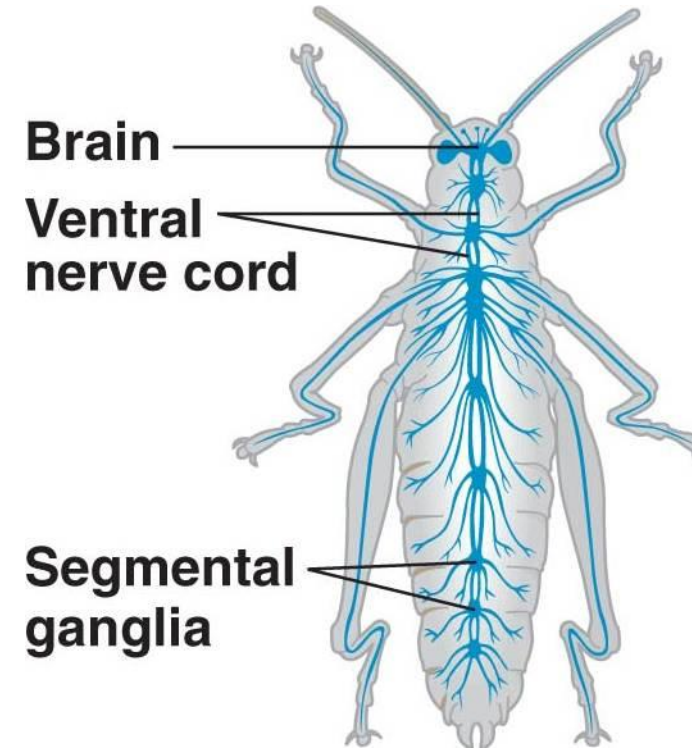
- Worms
  - Segmented nervous system
  - Left – right coordination
  - Ganglia
  - „Brain“ ganglion – head – forward locomotion – food intake



<https://en.wikipedia.org/wiki/Earthworm>

# The logic of evolution of the nervous system

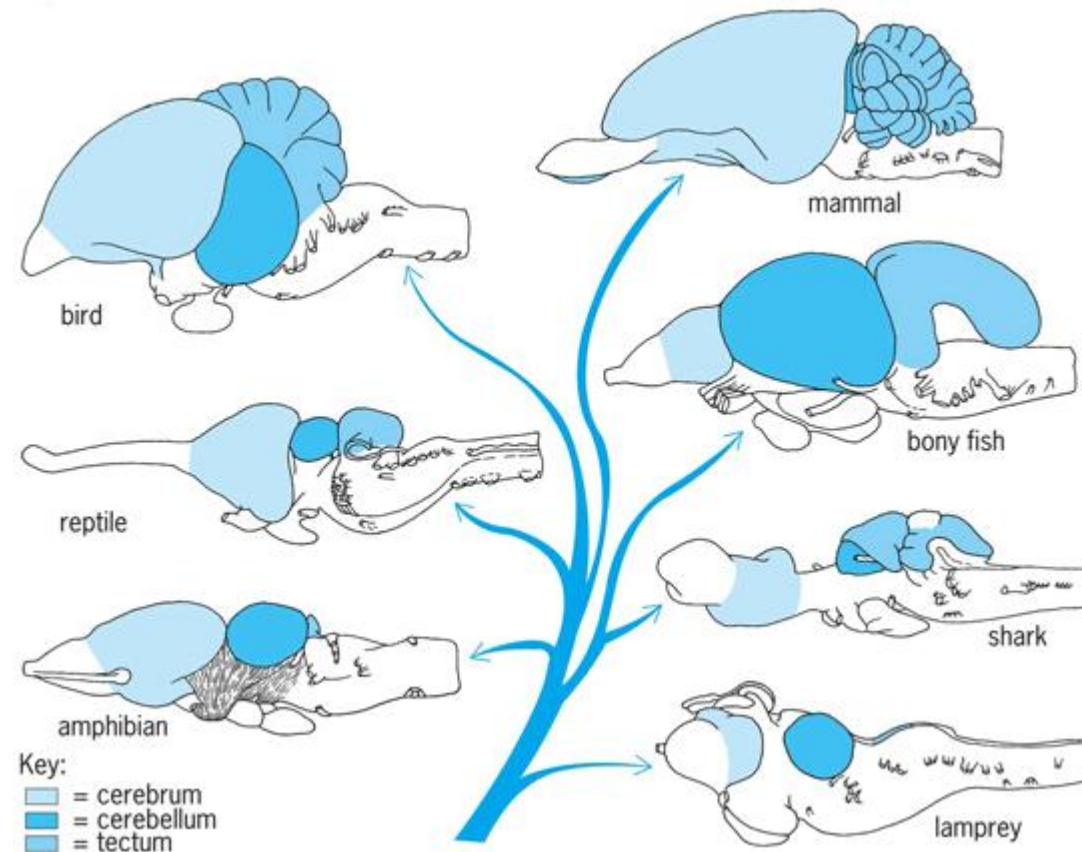
- Insect
  - „Sophisticated“ NS
  - Coordinated movement
  - „Developed“ senses
  - Communication skills (bee)
  - Social structures



<http://bilingualbiology10.blogspot.cz/2013/08/topic-11b-arthropods-izeltlabuak.html>

# The logic of evolution of the nervous system

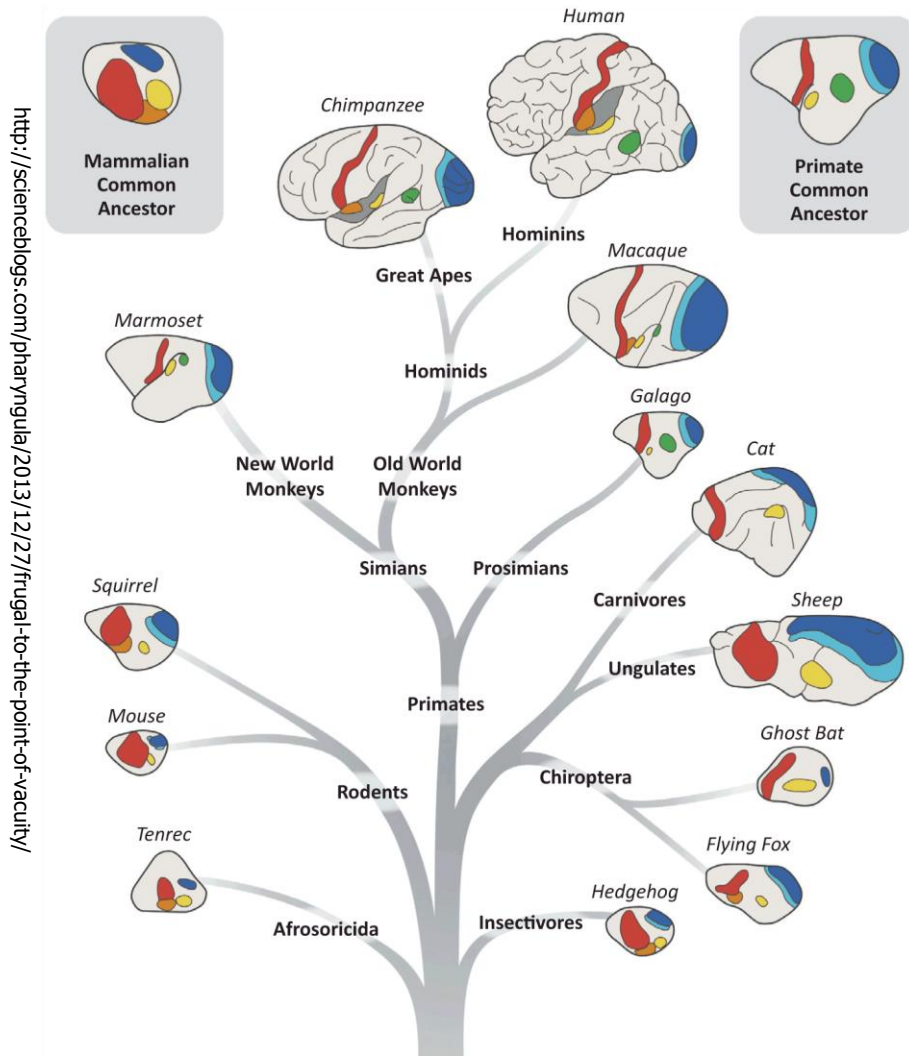
- Vertebrates
  - Cartilaginous or bony protection of CNS
  - Real brain
  - Very sophisticated NS
    - Coordinated movement
    - Senses
    - Social structures
    - Intelligence
- ✓ Fishes (intelligence)
- ✓ Amphibians
- ✓ Reptiles (emotions)
- ✓ Birds and mammals (the top of evolution)



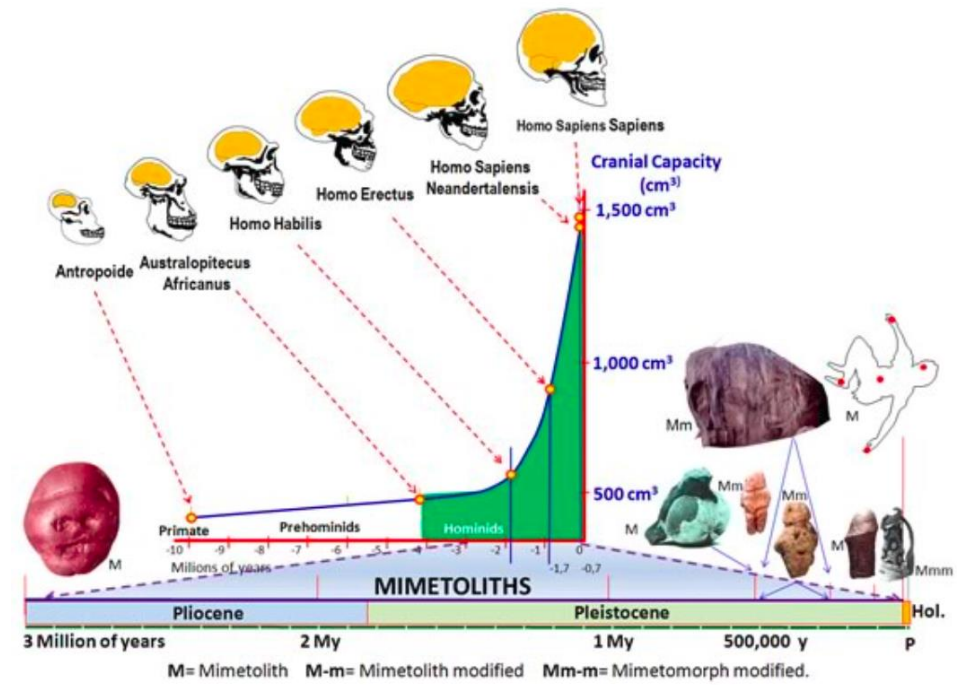
Northcutt RG, Noback CR, Kallen B. Nervous system (vertebrate). *Access Science* [Internet]. 2020 [cited 2021 Sep 17]; Available from: <https://www.accessscience.com/content/nervous-system-vertebrate/449300>  
Copyright © McGraw Hill



# The logic of evolution of the nervous system



**Evolution is shaped by environment**



<http://www.rupestreweb.info/mimesis.html>

# Basics of behavior enabling survival

- **Multipurpose movements**
  - The most basic actions of individual organisms
  - **Locomotion**: to approach or to avoid something
  - **Orienting**: towards or away from something
  - **Exploring/foraging/seeking** (includes the first two plus motivation)

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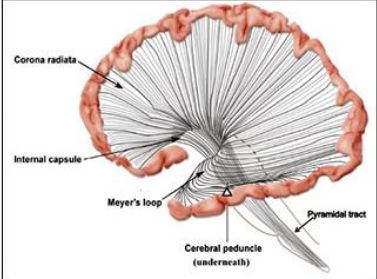
LECTURE NOTES

AUDIO LECTURES

ASSIGNMENTS

EXAMS

STUDY MATERIALS



**Instructor(s)**  
Prof. Gerald E. Schneider

**MIT Course Number**  
9.14

**As Taught In**  
Spring 2014

**Level**  
Undergraduate

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Drawing of the left hemisphere of the human brain together with the brainstem, dissected to reveal the course of axons that descend to the brainstem and spinal cord. (Courtesy of MIT Press. Used with permission. Figure 22.8 from Schneider, G. E. [Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind](#). MIT Press, 2014.)

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- > [Subtitles/transcript](#)
- > [Lecture notes](#)
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- **Background (maintenance) activity**
  - respiration, temperature regulation, postural reflexes

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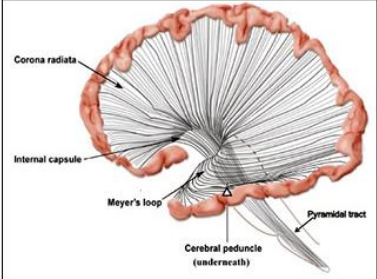
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- **Motivation**

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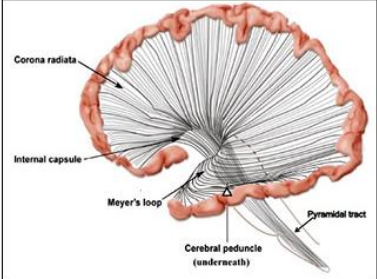
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# Basics of behavior enabling survival

- **Multipurpose movements**

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- **Locomotion:** to approach or retreat

- **Orienting:** toward or away from

- **Exploring**  
plus movements

- **Background**

- respiratory  
reflexes

- **Motivation**

**Locomotion influenced development of**

- **Sensory analyzing mechanisms**

- Connected to inputs from cranial nerves

- **Associated motor apparatus**

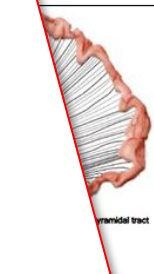
- For directing the receptors (orienting movements)
- For controlling alterations in posture and locomotion under guidance from these receptors

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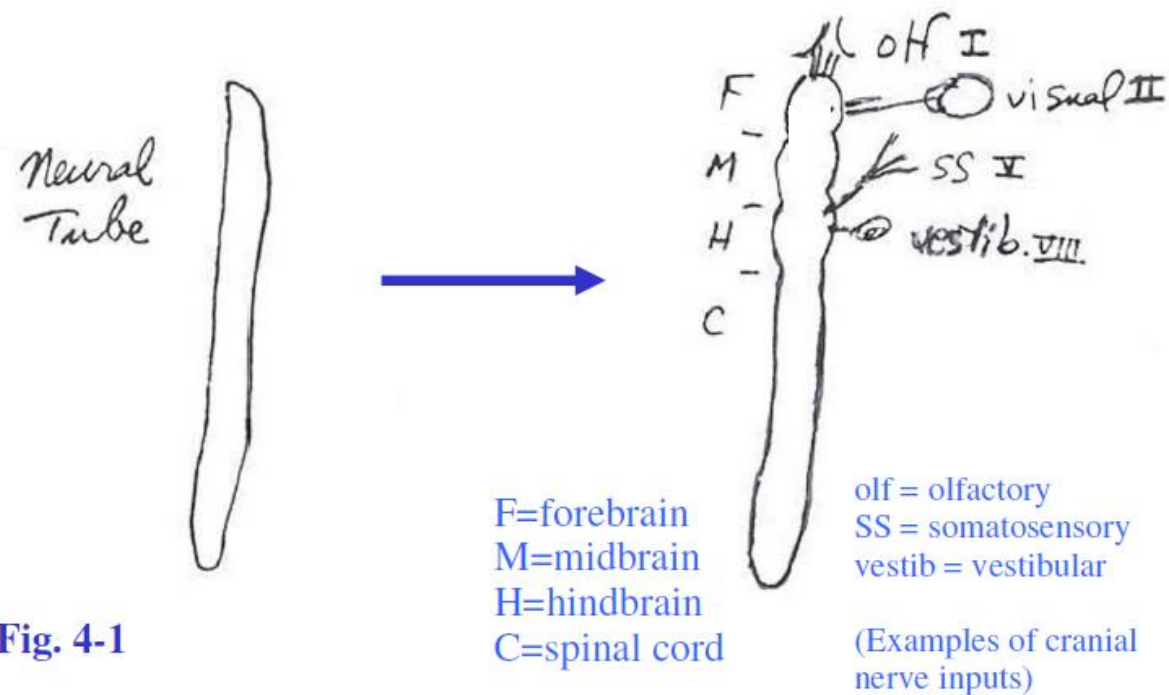
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# Evolution of the brain

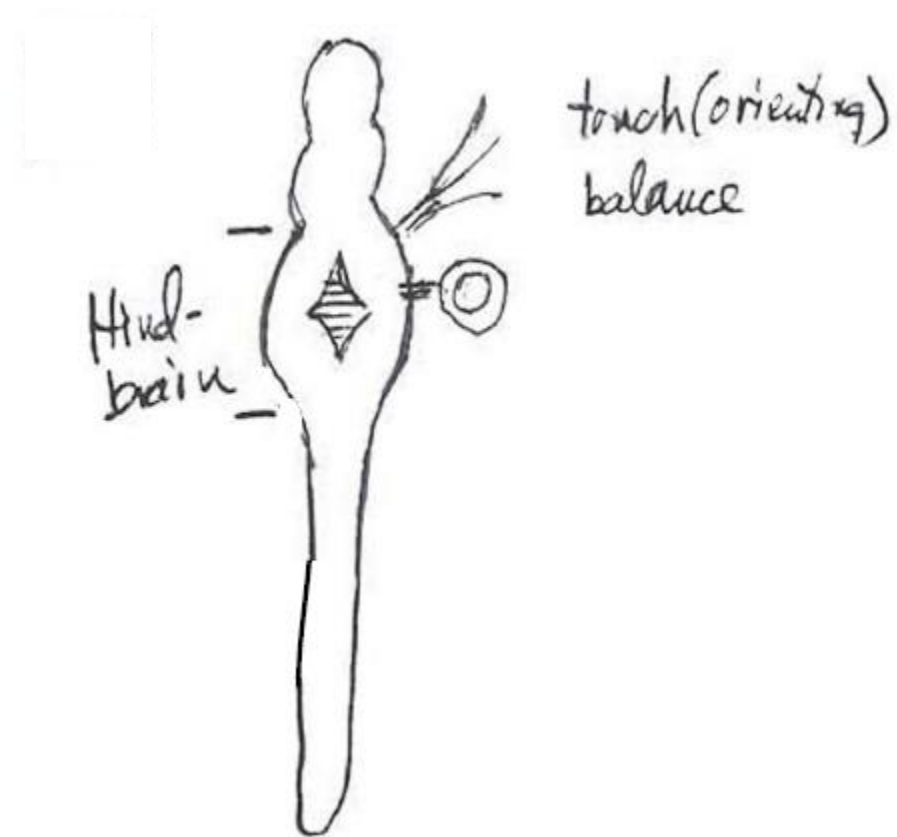
- Neural tube
- Locomotion
- Rostral receptors



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# Evolution of the brain

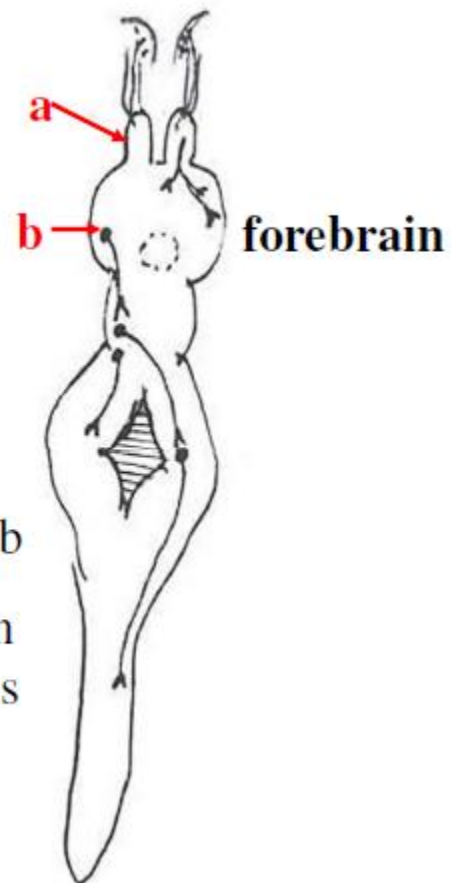
- **Expansion of hindbrain**  
(Rhombencefalon - Medula oblongata, pons Varoli, cerebellum)
- **Input**
  - Information from head sensors
- **Output**
  - Motor system  
(Fixed action pattern - reflex/instinct behavior)



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# Evolution of the brain

- **Expansion of forebrain 1**  
(Prosencephalon - diencephalon, telencephalon)  
(simultaneously with hindbrain)
- **Input**
  - Olfaction (Approach/avoidance)
- **Output**
  - Motor system  
(via corpus striatum)



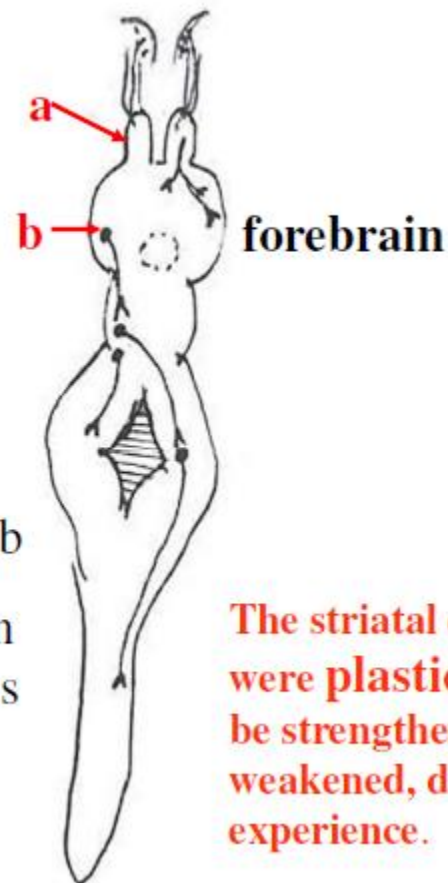
**a** olfactory bulb  
**b** connection in primitive corpus striatum

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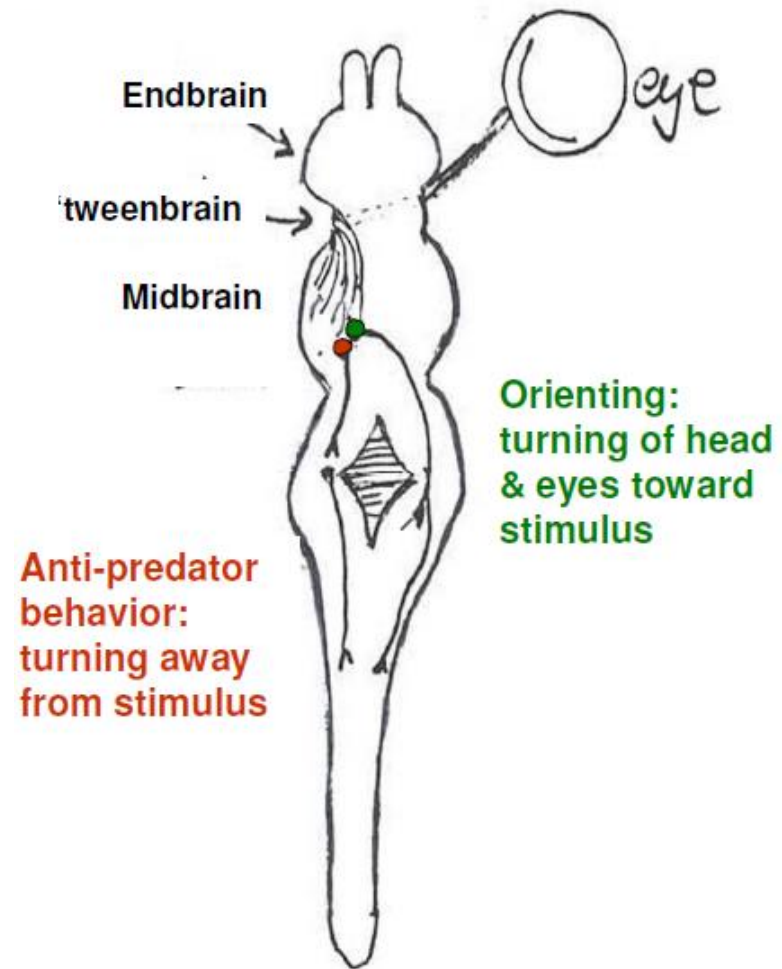
**a** olfactory bulb  
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**The striatal connections were plastic: They could be strengthened or weakened, depending on experience.**

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# Evolution of the brain

- **Expansion of midbrain**
- **Input**
  - Vision, audition (distant senses)
- **Output**
  - Motor system  
(Approach – contralateral m.)  
(Avoidance – ipsilateral m.)
- **Advantage**
  - Speed
  - Acuity



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# Evolution of the brain

- **Expansion of forebrain 2**

(Prosencephalon - diencephalon, telencephalon)

- **Input**

- Nonolfactory systems connected to forebrain
- Mainly vision and hearing

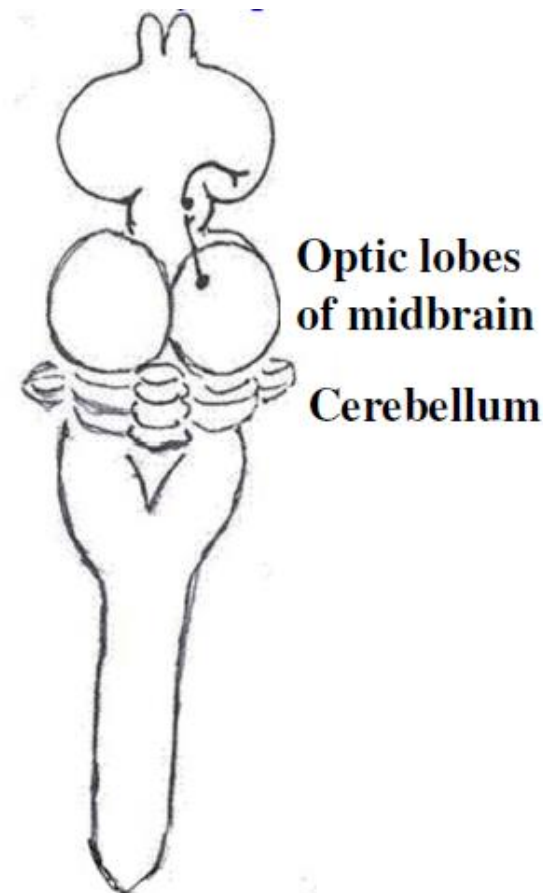
- **Advantage**

- Plastic connections of forebrain

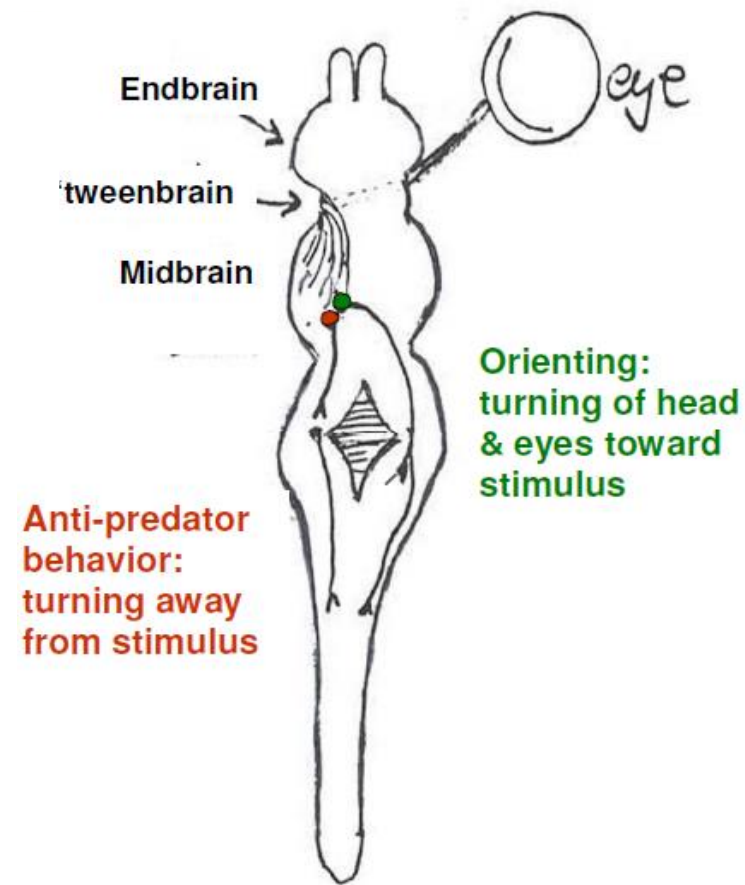
- **Thalamus**

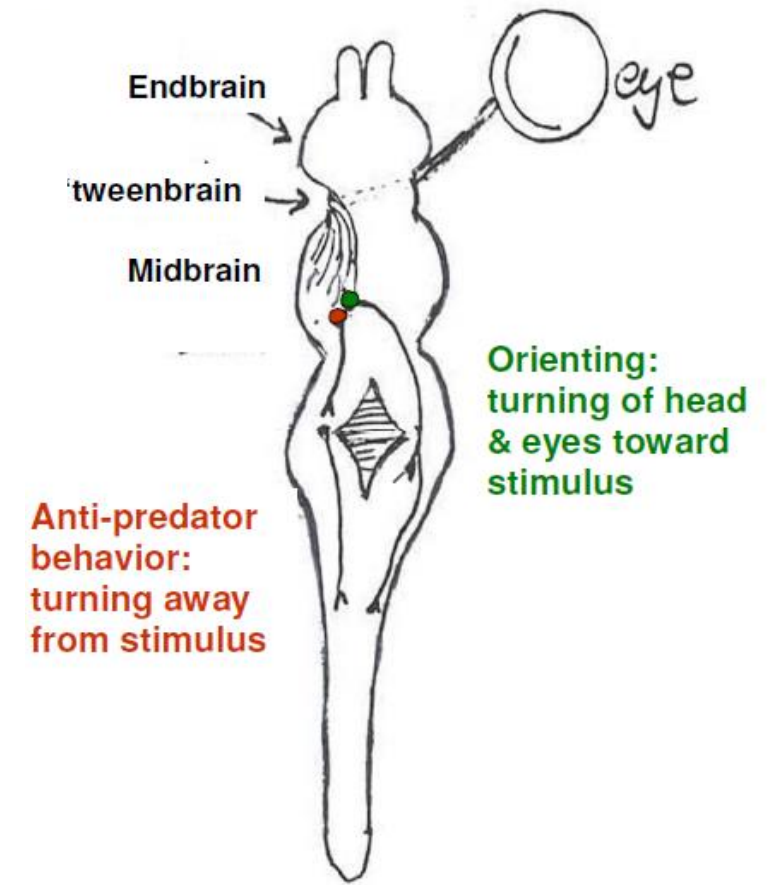
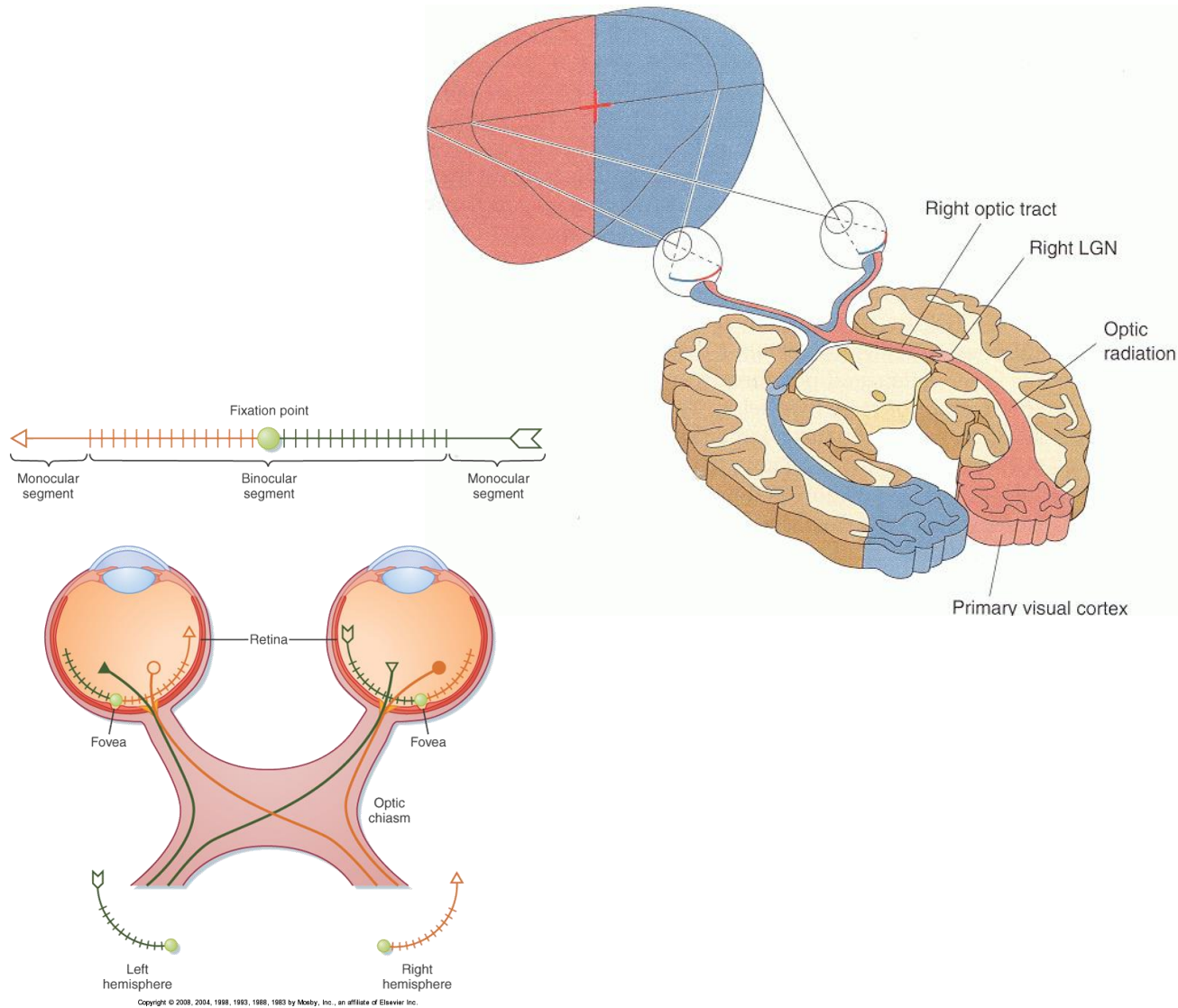
- Gating

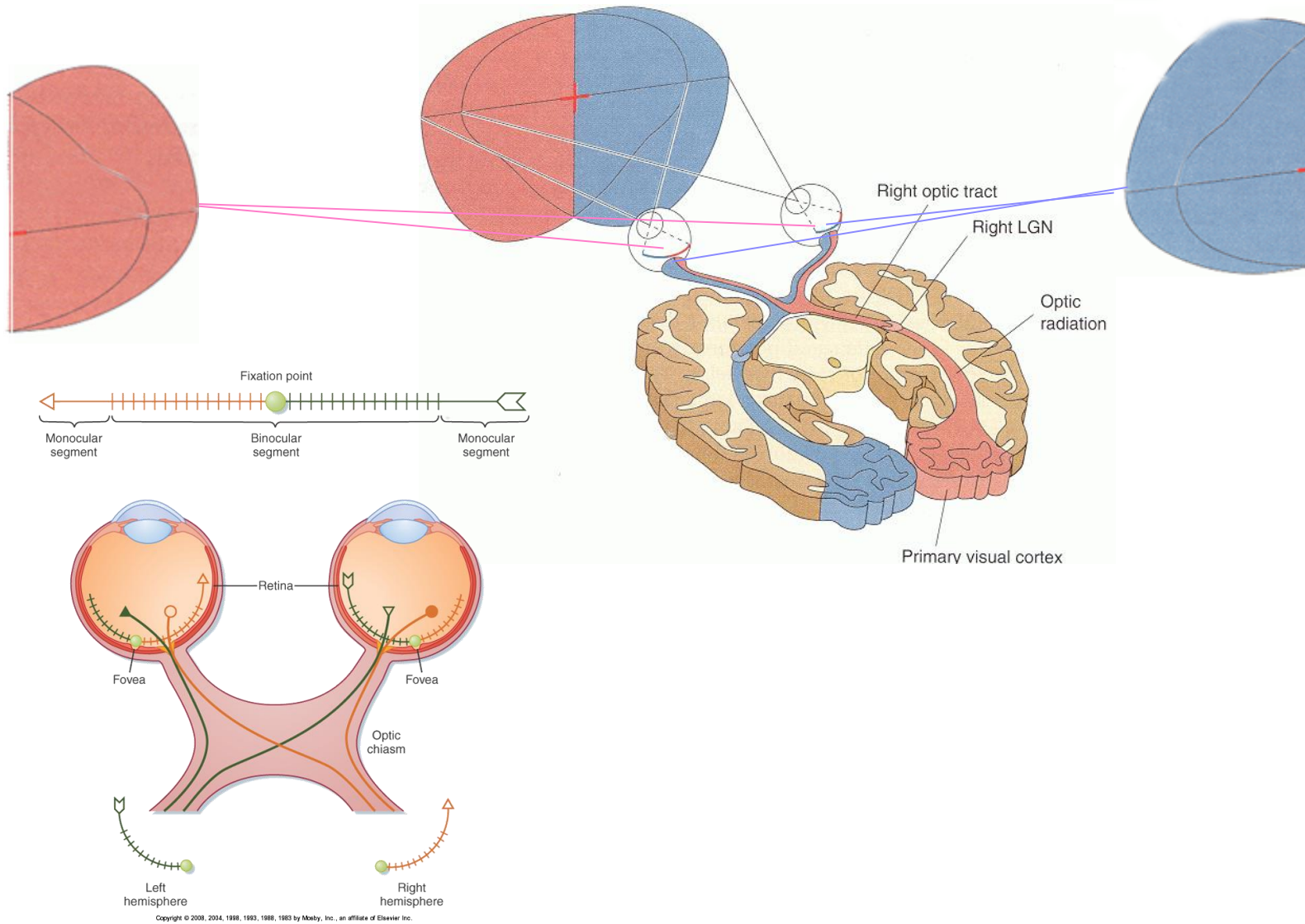
(Corpus striatum and cortex)



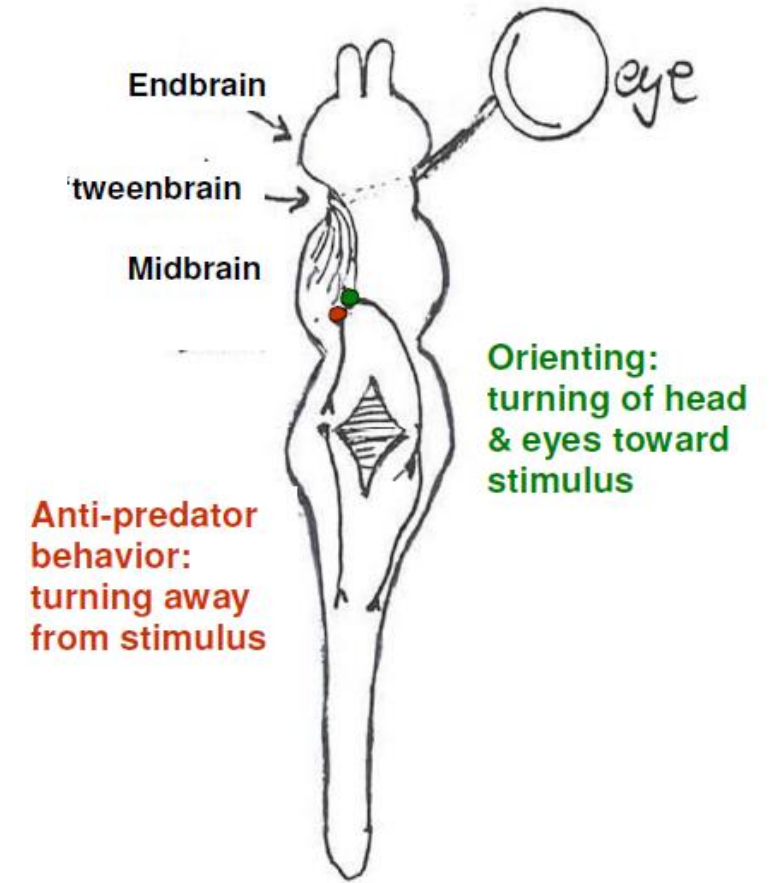
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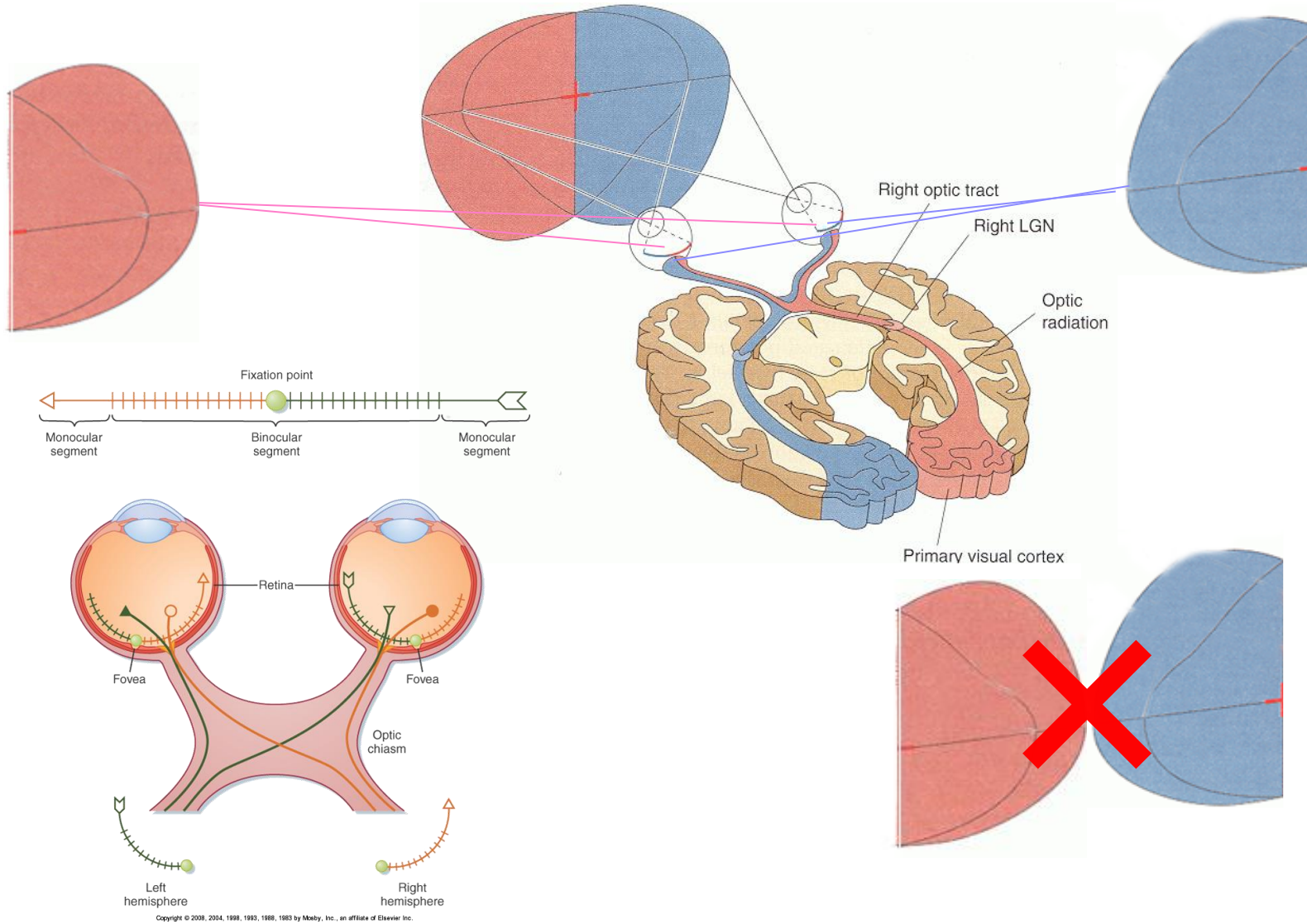




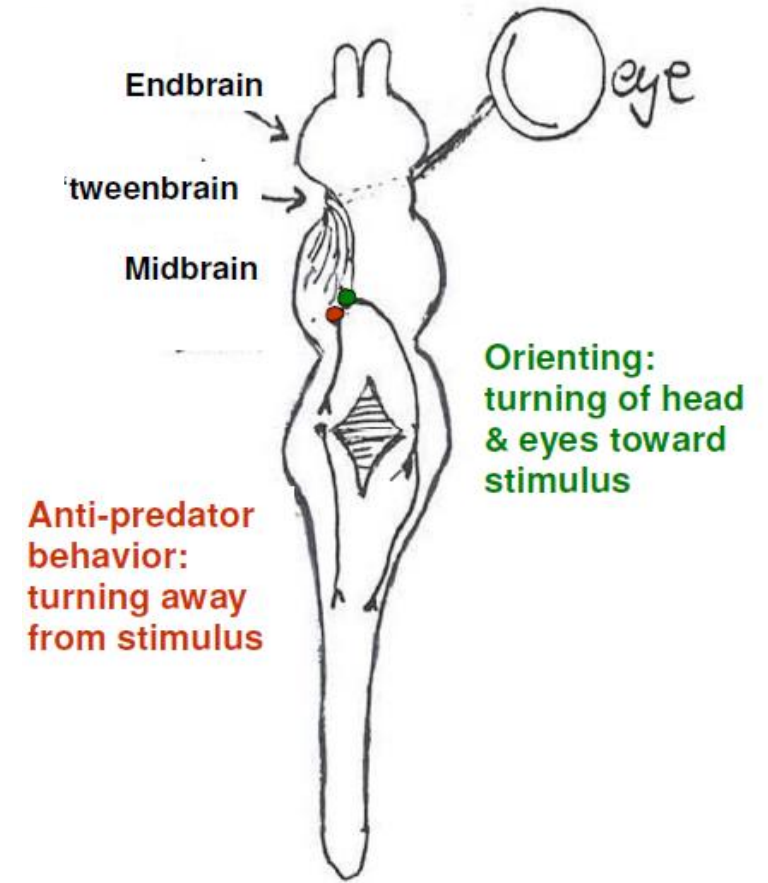


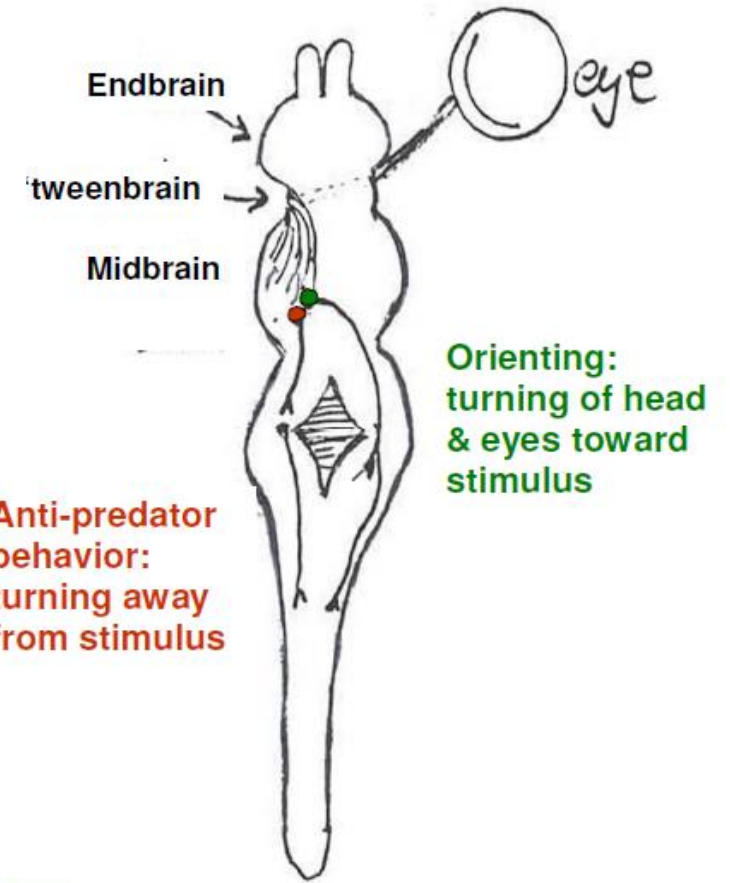
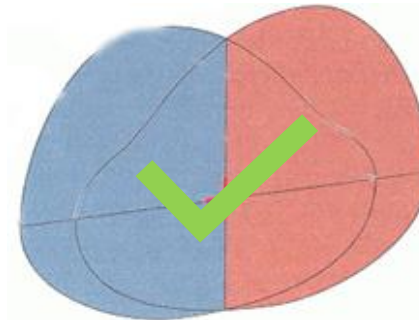
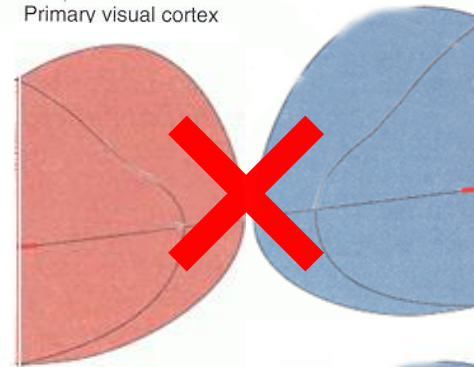
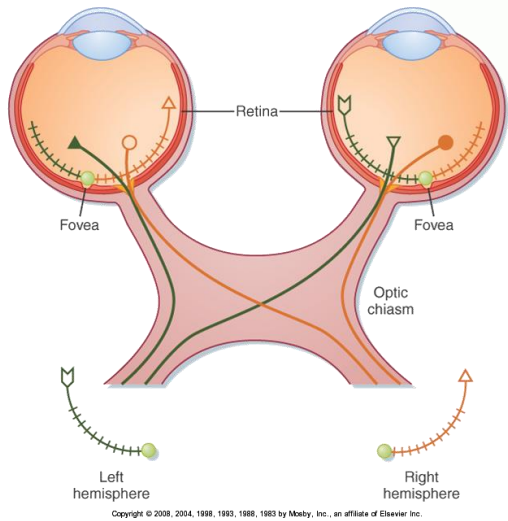
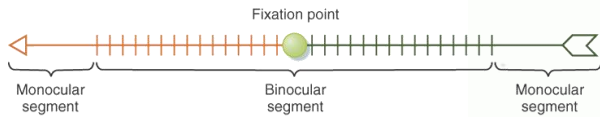
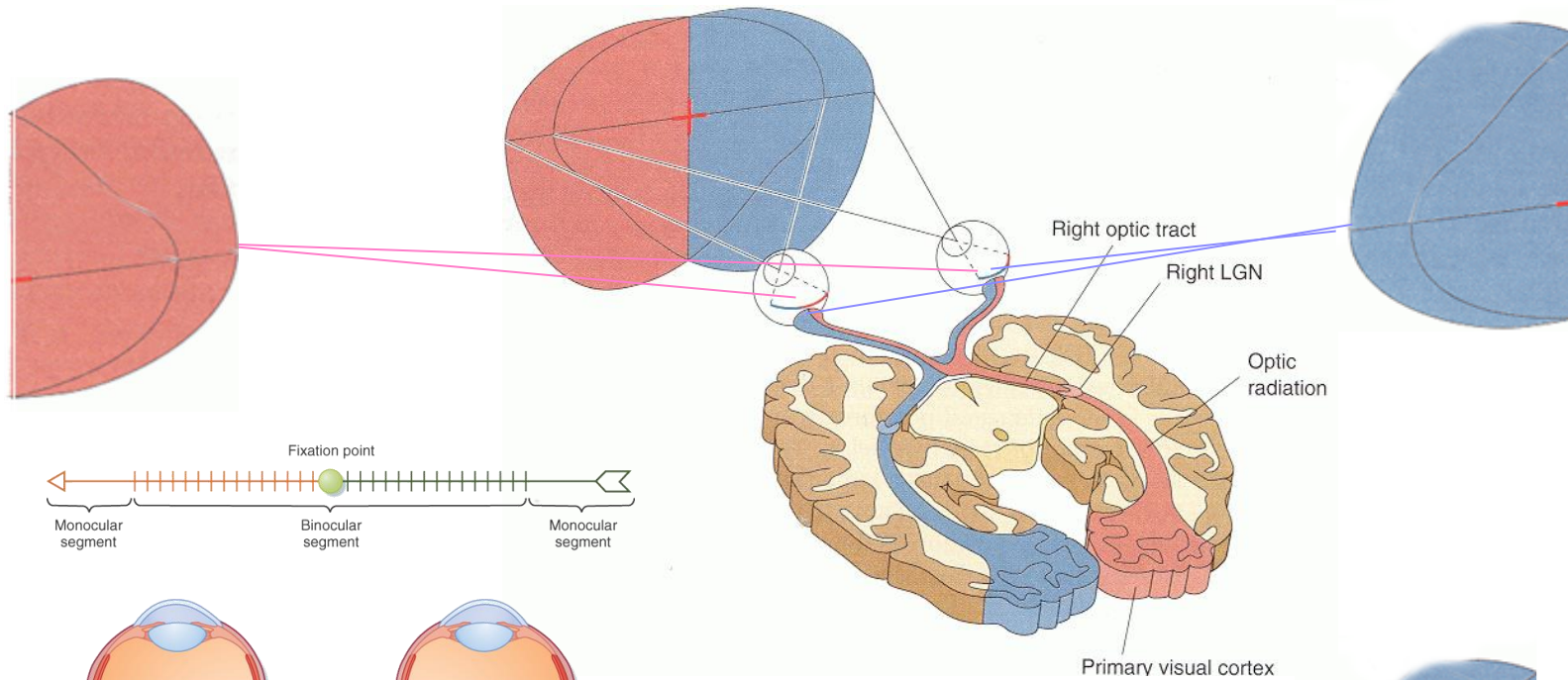
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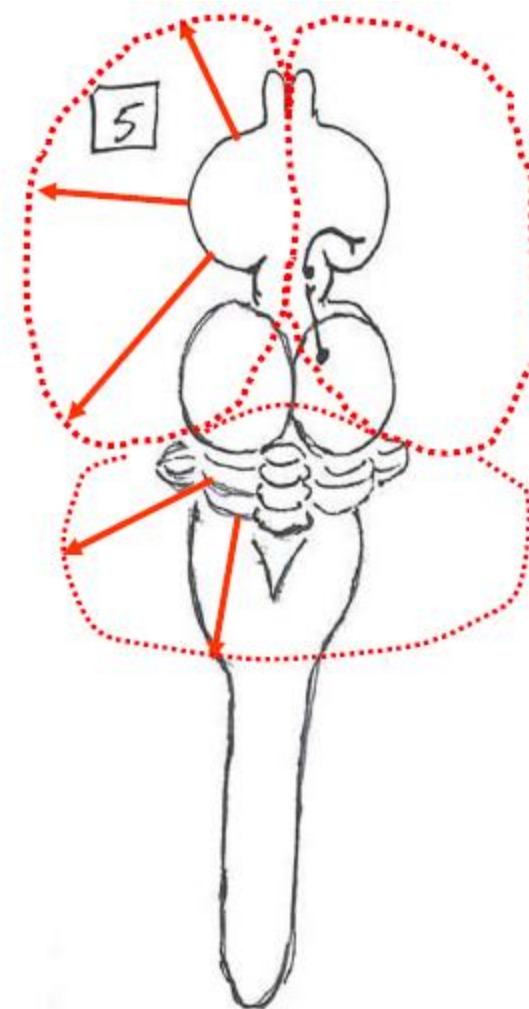






# Evolution of the brain

- **Expansion of forebrain 3**
- Neocortical expansion
- Simultaneous expansion of
  - Neostriatum
  - Neocerebellum
- Advantage
  - „High resolution“ information processing
  - Anticipation

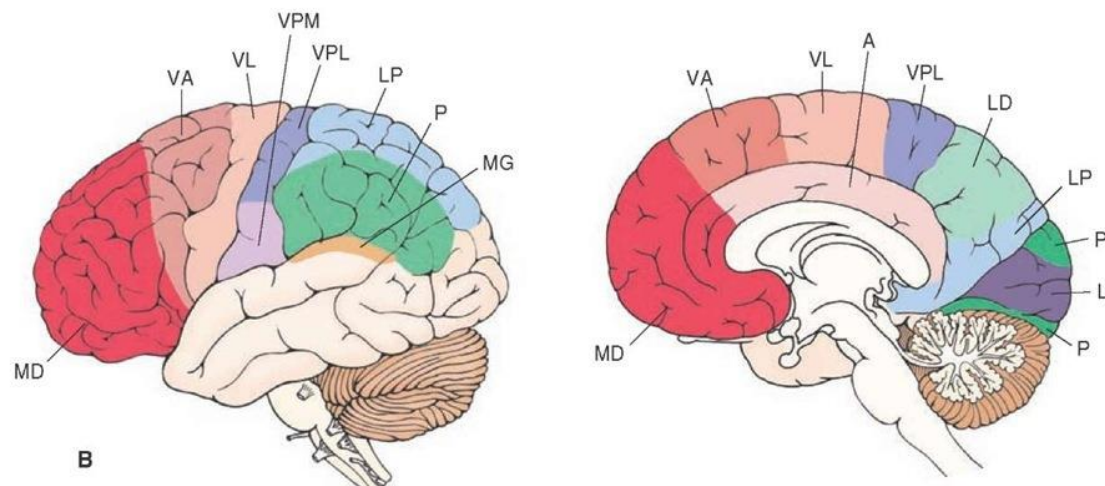
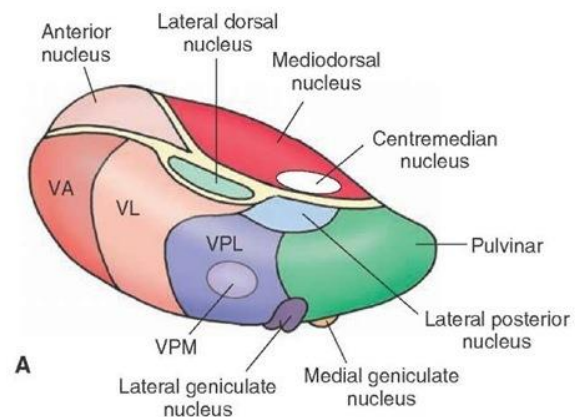


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# Thalamus and neocortex

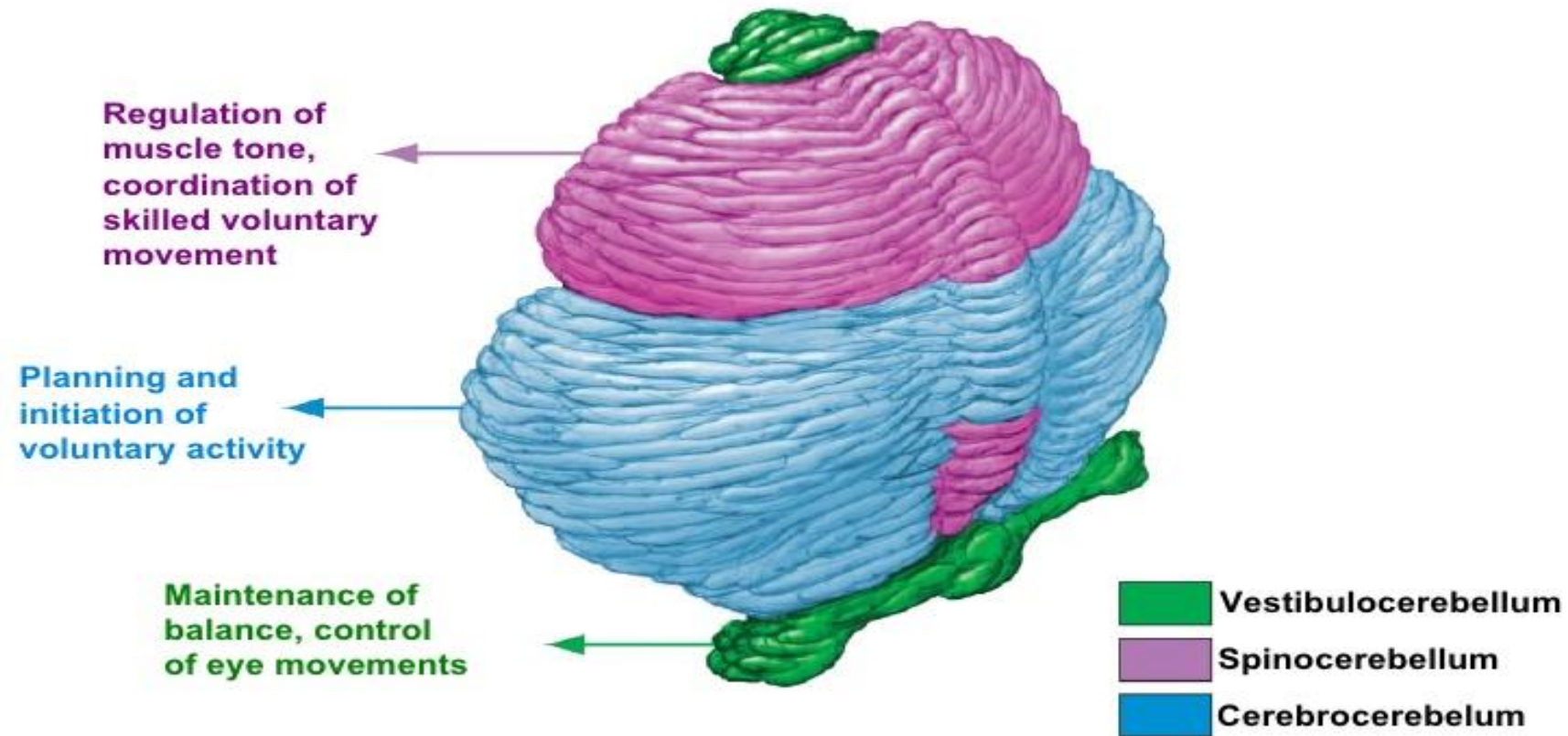
## Gating

- Thalamic nuclei
  - Nonspecific
  - Specific
- Reciprocal connections between thalamus and neocortex



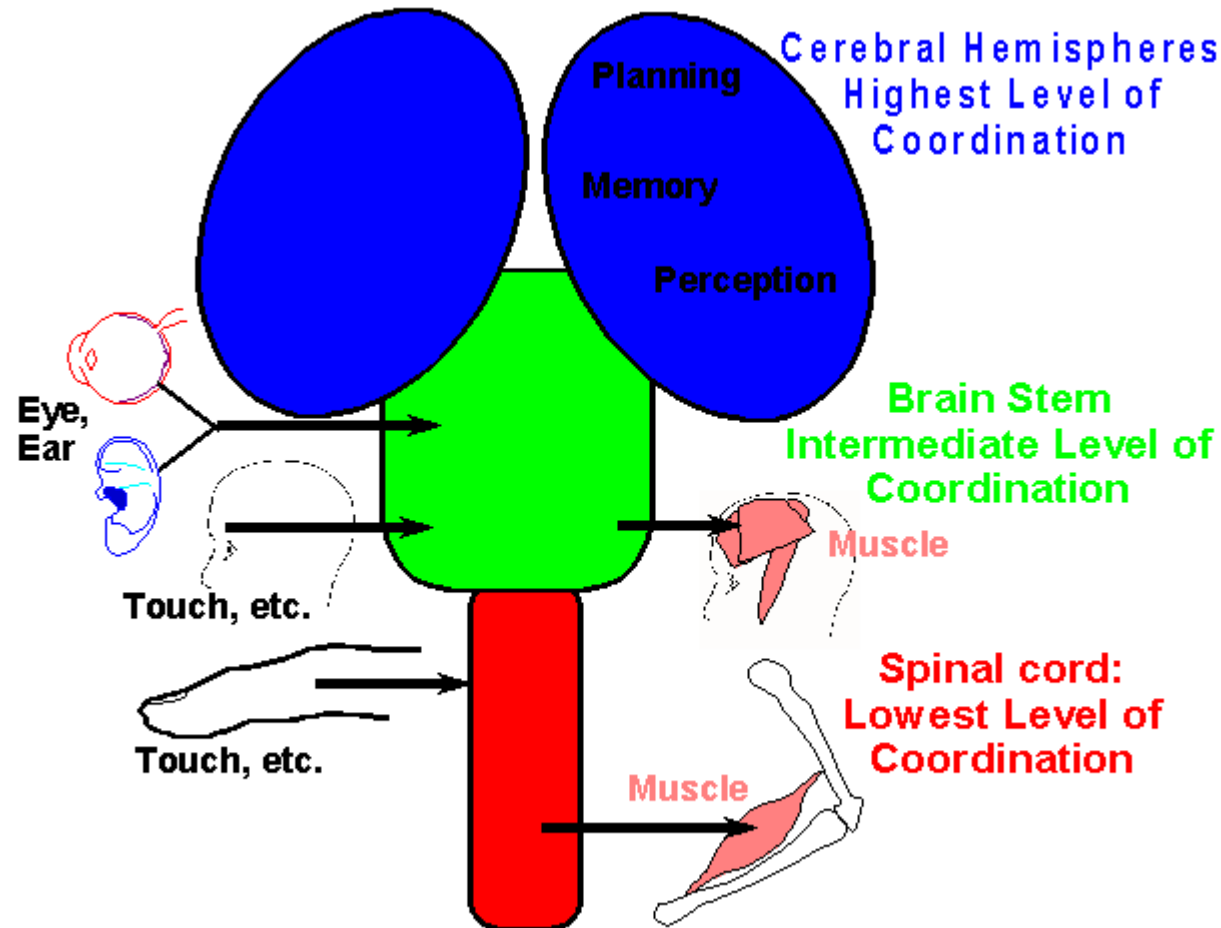
# Cerebellum

## Coordination

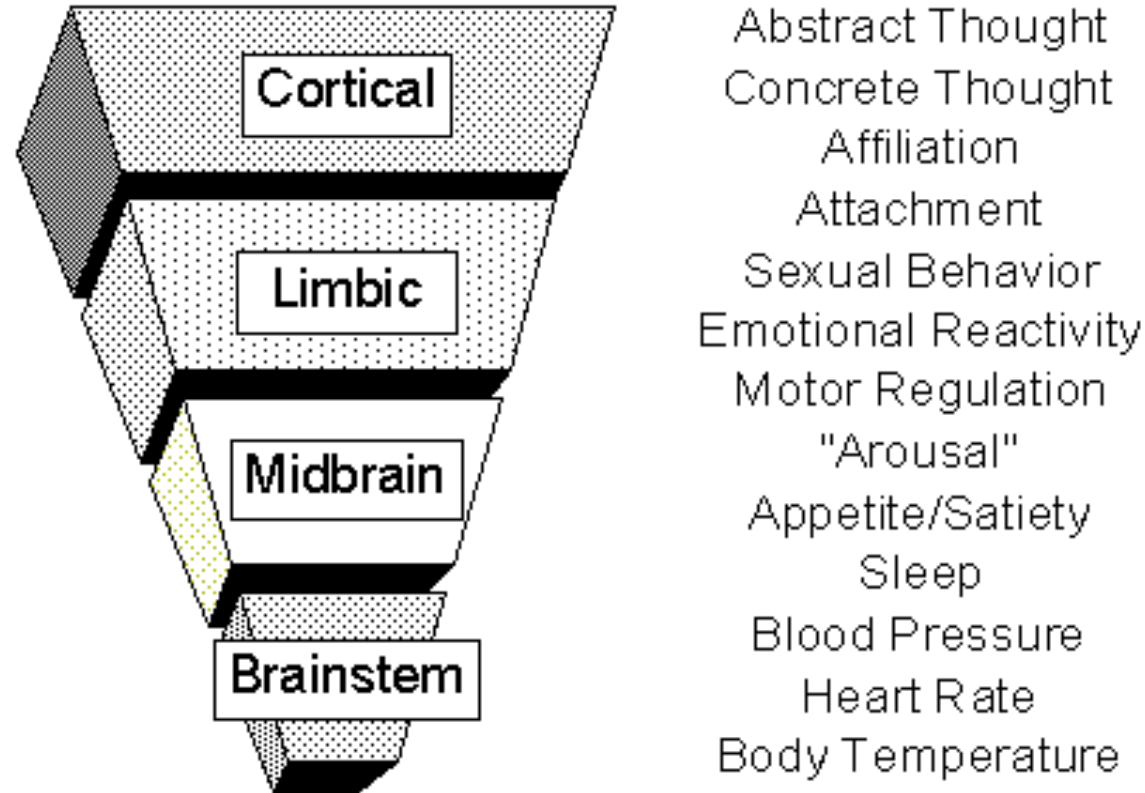


<http://www.slideshare.net/HarshshaH103/cerebellum-its-function-and-relevance-in-psychiatry>

# Hierarchy of central nervous system

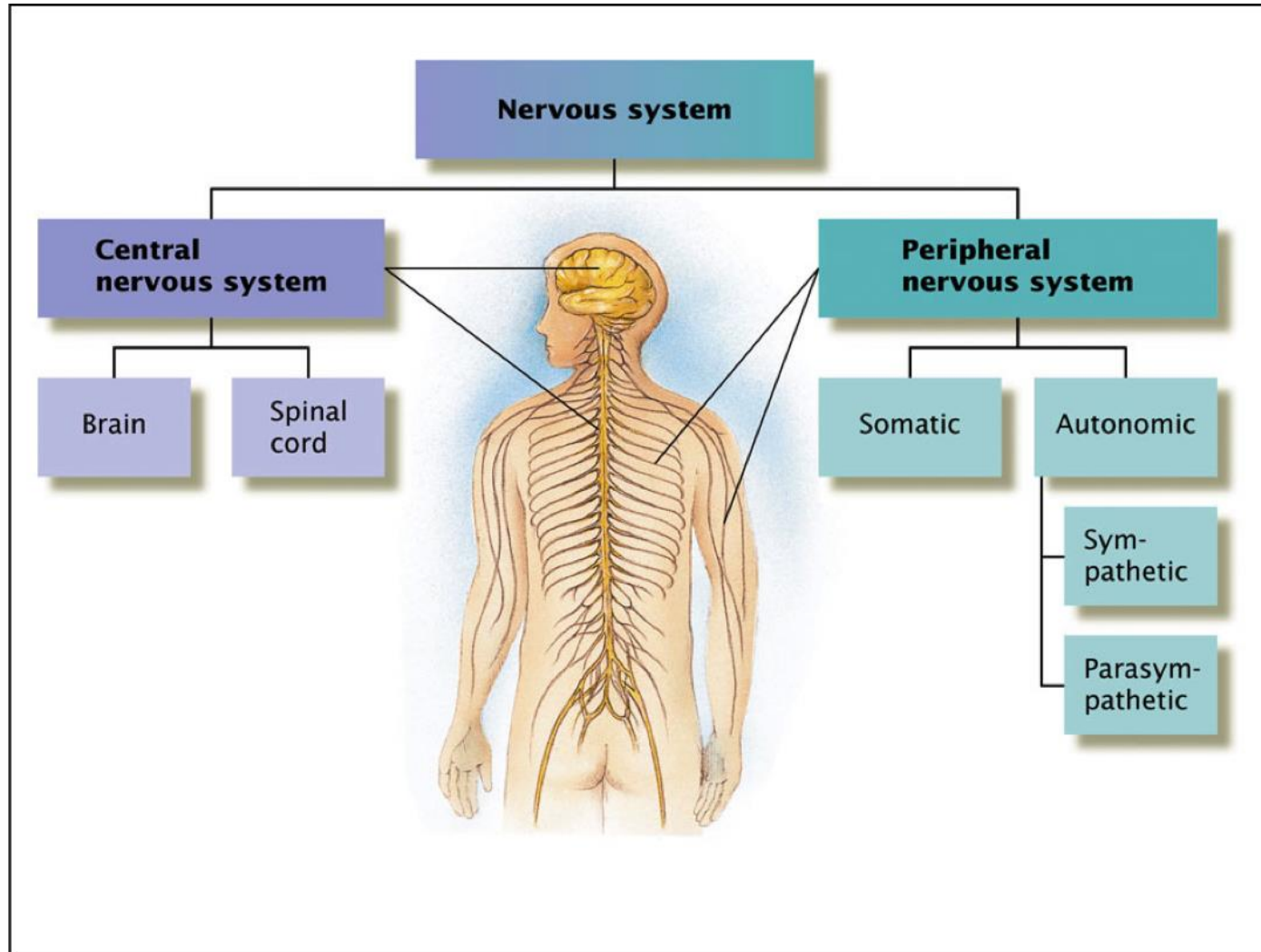


# Hierarchy of central nervous system



<https://rajugurusamy.files.wordpress.com/2007/11/memories1.gif?w=497>

# Hierarchy of nervous system



<https://userscontent12.emaze.com/images/be175f0a-afae-4c7c-944c-f6376cf09ba/60c3e8a3-a6b9-4a3d-943d-1841136a9ccf.png>

M U N I

M E D