
F4
Cognitive Systems
2020 edition
Marcio Lobo Netto
João E. Kogler Jr.
cognitio

PSI 3560 – COGNITIVE SYSTEMS

class F4

Marcio Lobo Netto
João Eduardo Kogler Junior

Polytechnic School of the University of São Paulo
Department of Electronic Systems Engineering

SELECTED TOPICS ABOUT BRAIN AND MIND

Brain organization and functionalities, memory and representation

Session F4

cognitio

Summary

– First session (7:30 – 9:10)

- Neuroscience
  - Human brain organization
  - Human brain functionalities
- Cognitive Neuroscience
  - Mental correspondences
- Memory and representation

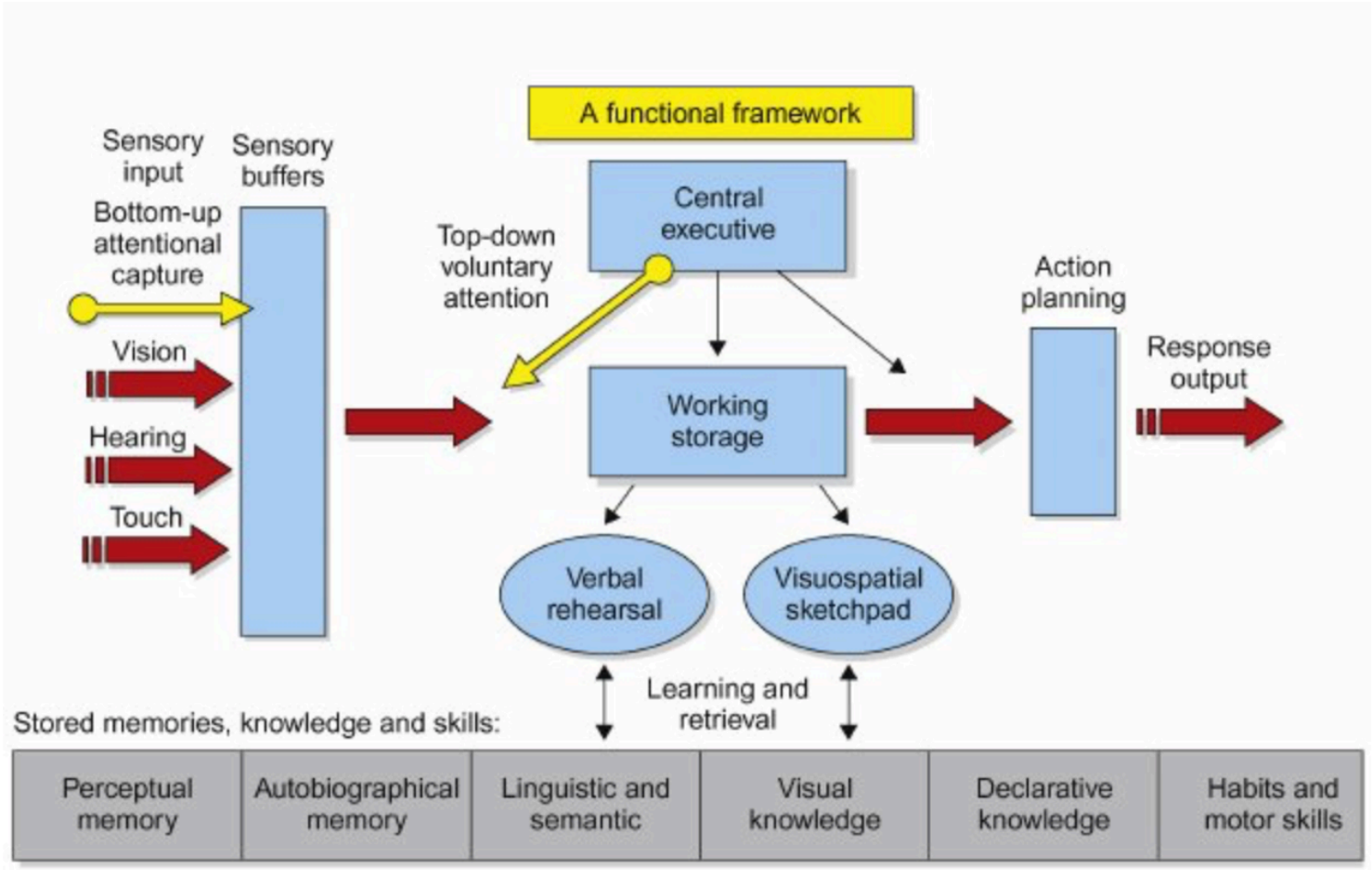
    - Coffee break

  - Second session (9:20 – 11:00)

Section 1

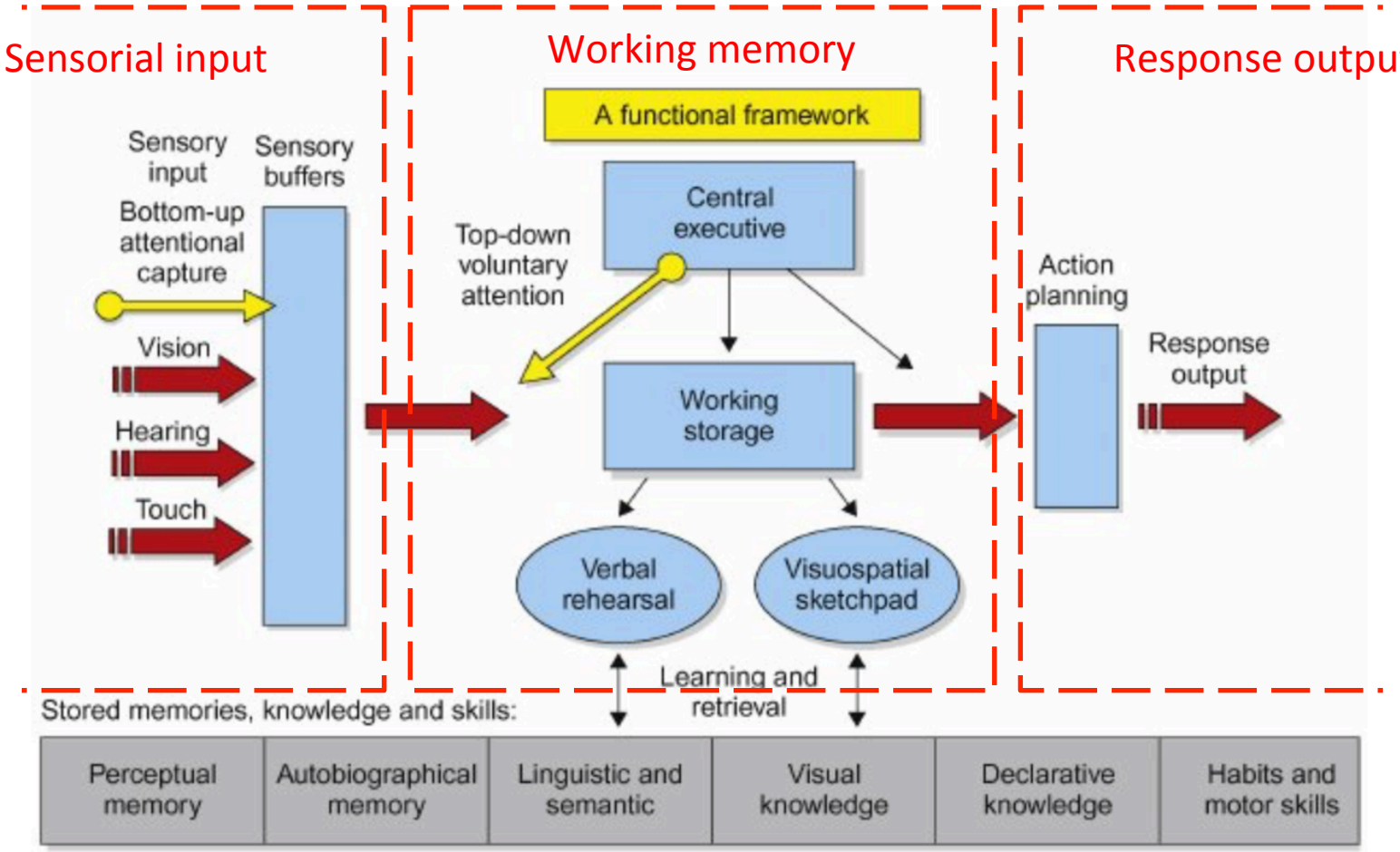
- Human Brain Organization & Functionality
  - Frameworks

Baars & Gage functional framework



Source: B.J. Baars & N.M. Gage – Fundamentals of cognitive neuroscience – Elsevier, 2013

Baars & Gage functional framework



Source: B.J. Baars & N.M. Gage – Fundamentals of cognitive neuroscience – Elsevier, 2013

Section 2

- Neuroscience – Macro Scale (organ: brain)
  - Human brain organization - anatomy
    - Circuits & Systems
  - Human brain functionalities - physiology

Neuroscience

- Observations and studies performed at different levels
  - from molecular (neurotransmitters)
  - through cellular (neurons)
  - to systemic (brain)
- Abstraction layers
  - from signal processing
  - to mental analysis
- Let´s see some of the high level ones

Human brain organization

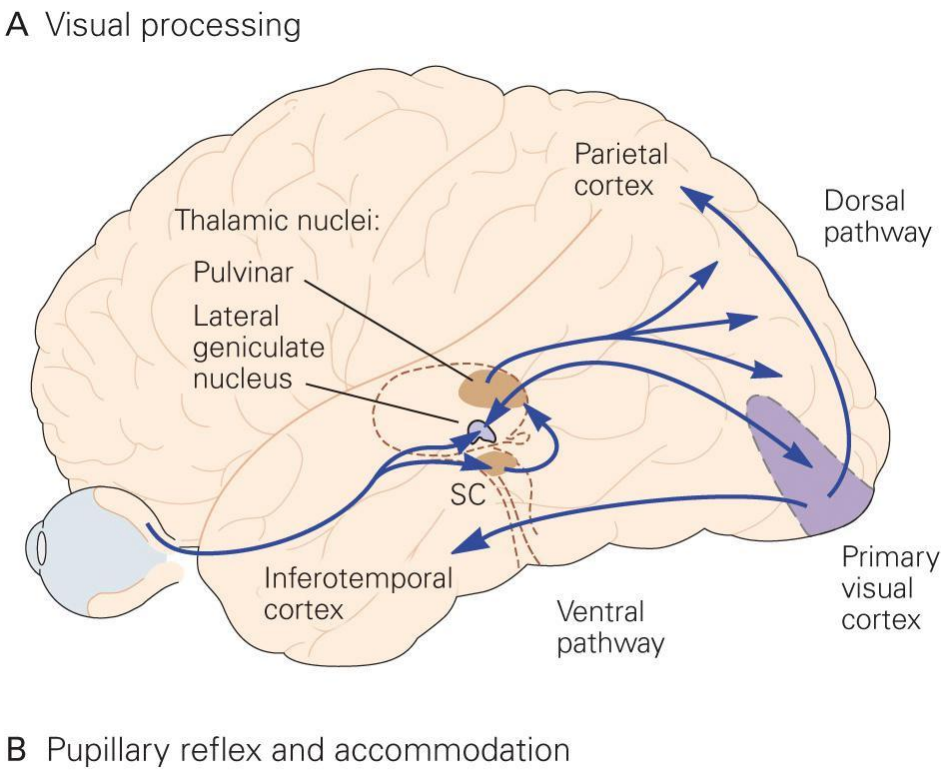
- Central Nervous System
  - Brain
    - Regions and structures
    - Cortical areas (newer)
    - Brain nuclei (older)
      - Thalamus
      - Hypothalamus
      - Striatum
  - Brain Stem
    - Cerebellum
    - Pons

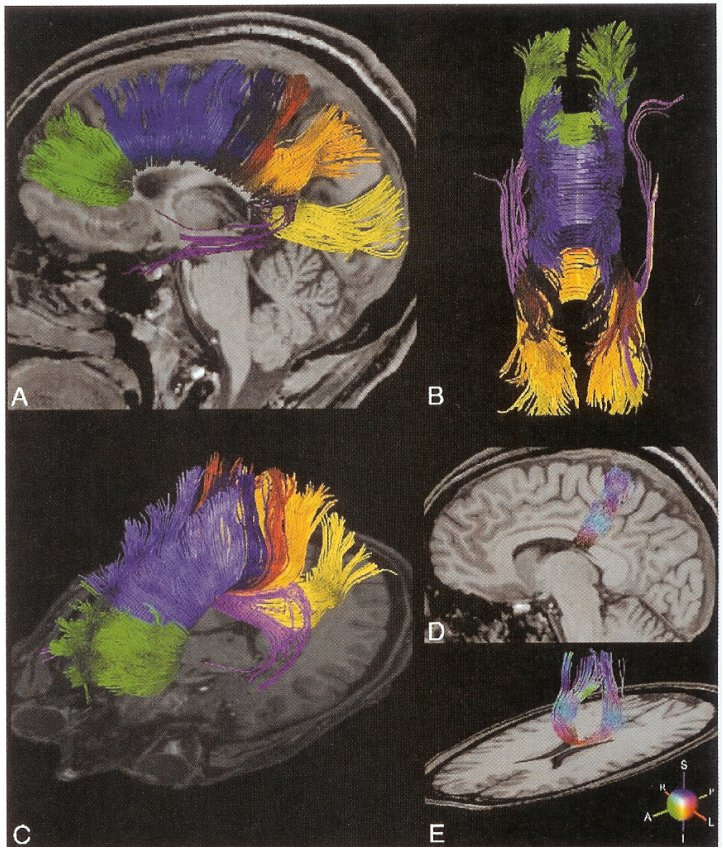
Human brain organization

- Peripheral Nervous System
  - Medulla

Neuroscience – macro scale

- Circuits & Systems





Neuroscience – macro scale

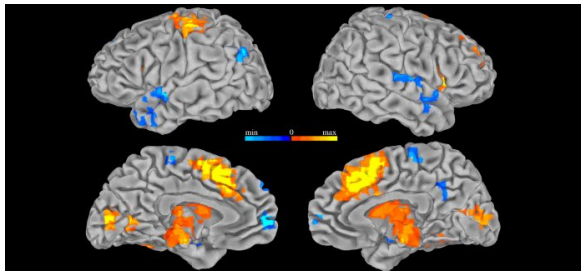
- Neuro Anatomy
  - Structural analysis (volumetric visualization / slices)
  - Higher spatial resolution
  - Time invariant (photo)

- Instruments & Technologies
  - CT (Computer Tomography)
  - MRI (Magnetic Resonance Imaging)

- Observation of neural tissues
  - Eventual malformations
  - Eventual acidentes

Neuroscience – macro scale

- Neuro physiology
  - Functional analysis (volumetric visualization / slices)
  - Lower spatial resolution
  - Time variant (video)



- Instruments & Technologies
  - PET (Positron Emission Tomography)
  - fMRI (functional Magnetic Resonance Imaging)

- Observation of brain activities
  - Eventual malfunctions
  - Damaged operations

Neuroscience – macro scale

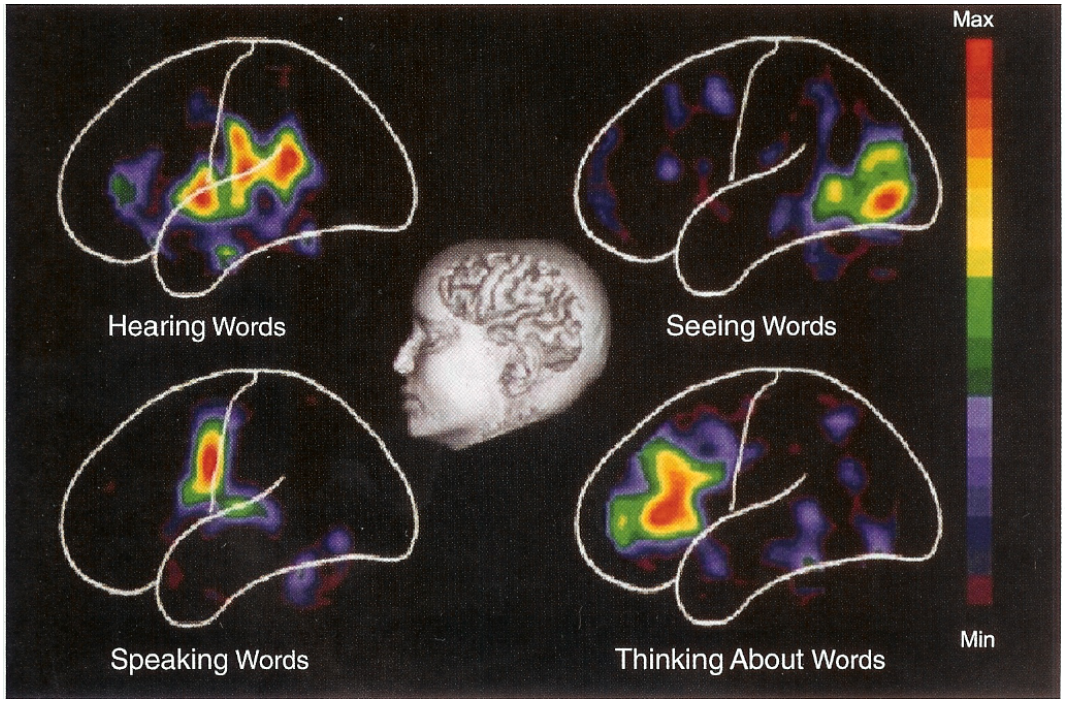
- fMRI equipment

Section 3.1

- Cognitive Neuroscience – Mental
  - Brain – Mind correspondences
  - Brain – Mind functionalities
  - Language

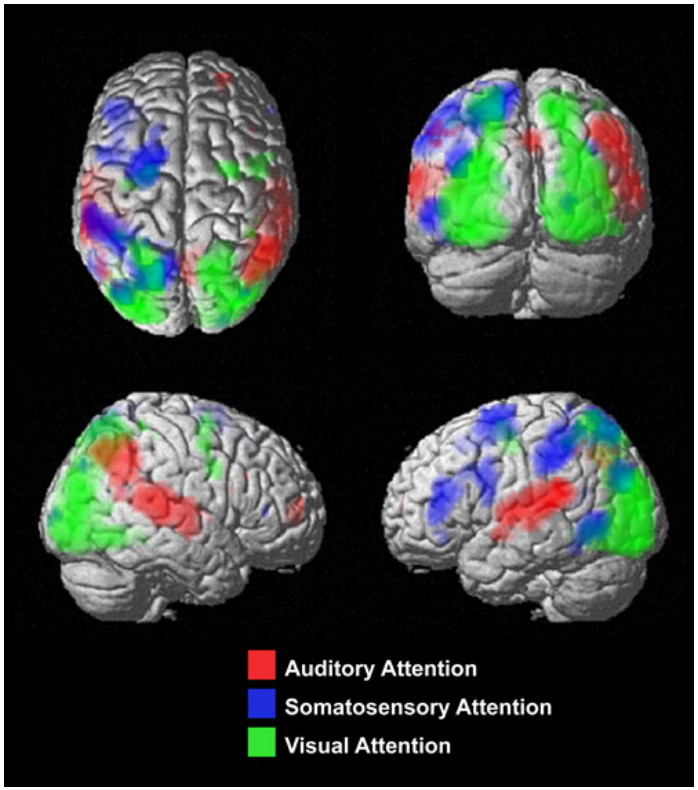
Cognitive Neuroscience

- macro observation by medical exams
- PET: Positron Emission Tomography
  - Brain areas and involved in different tasks
    - Hearing
      - Wernick
    - Speaking
      - Broca / Motor
    - Vision
      - Occipital
    - Thought
      - Frontal



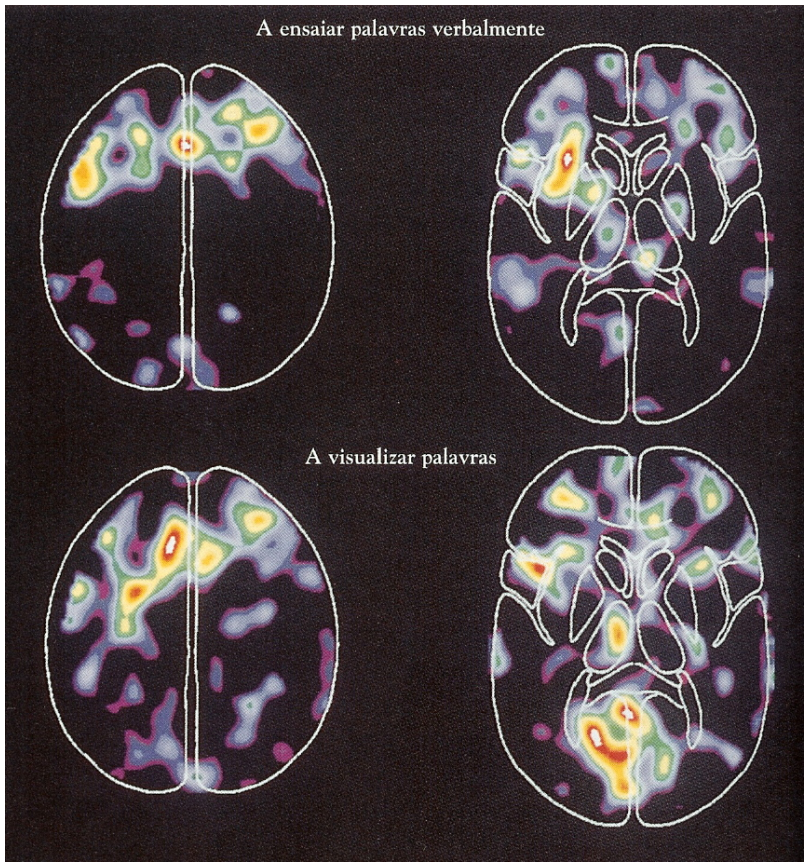
Cognitive Neuroscience

- macro observation by medical exams
- fMRI: functional Magnetic Resonance Imaging



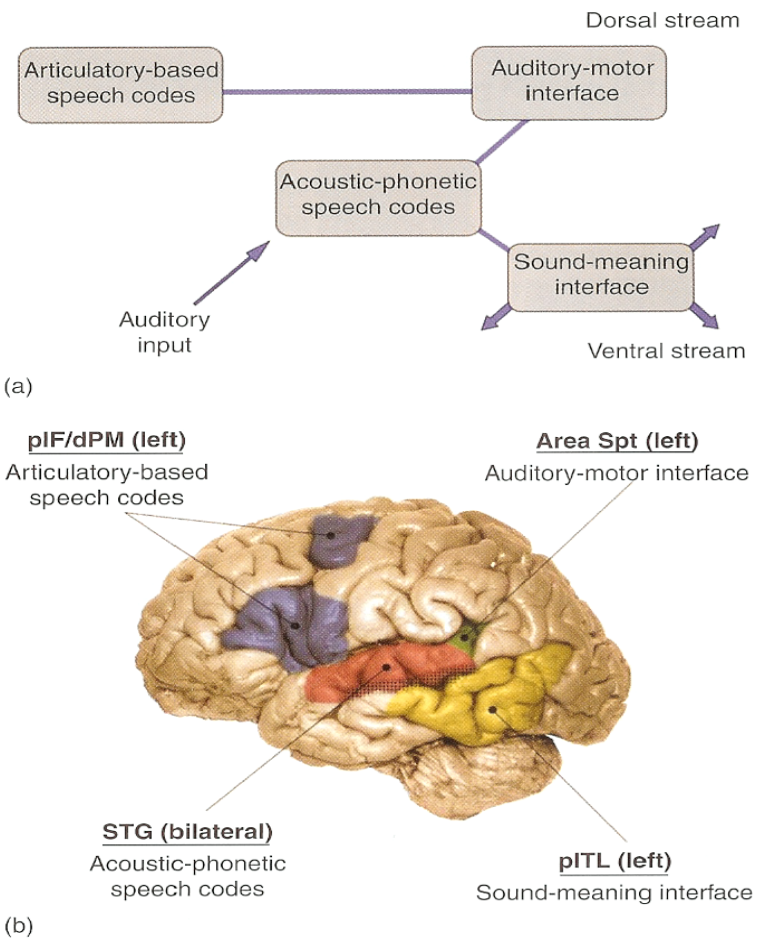
Cognitive Neuroscience

- Communication and Language
  - Brain areas involved in these tasks
    - Searching for words
      - Frontal (integration)
      - Frontal (Broca - language)
    - Visualization of words
      - Frontal (integration)
      - Occipital (visual)



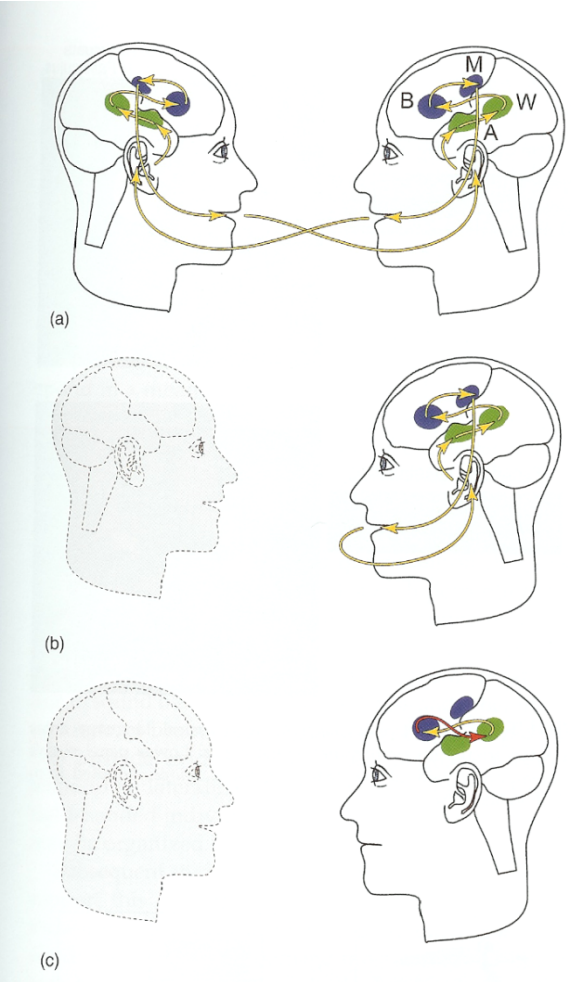
Cognitive Neuroscience

- Communication and Language
  - Dedicated centers for linguistic processing
    - Producing (speech)
      - Broca area
    - Comprehension (audition)
      - Wernick area



Cognitive Neuroscience

- Communication and Language
  - Dedicated centers for linguistic processing
    - Interlocution (Speaking/Listening)
      - Communication supported by Language
    - Thought (Self Reflection)
      - Loud and internal speak (closed circuit) – speaking to yourself
      - Reasoning supported by language



Section 3.2

- Cognitive Neuroscience – Perception
  - Stages
  - Proprioception
  - Tact
  - Odor & Taste

Cognitive Neuroscience

- Perception
  - Initial stages
    - Highly parallel processing
    - Signal based information (spatial–temporal)
      - vision: image with multi-spectral features
      - hearing: sound with multi-spectral features
      - Properly handled by
        - » Connectionist approach

Cognitive Neuroscience

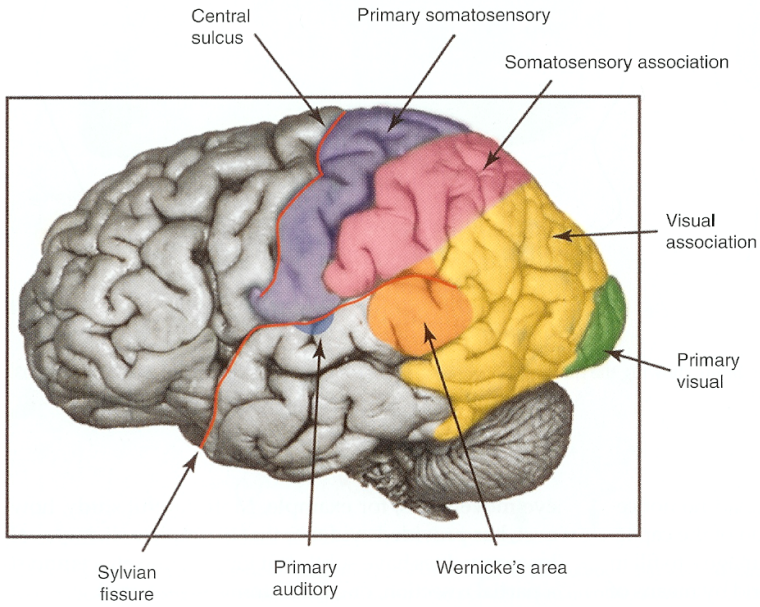
- Perception
  - Final stages
    - Increasingly sequential processing
    - Conscious mental character
    - Signal supported symbols (symbols chains - language)
      - Assigning concepts
      - Properly handled by
        - » Symbolic approach

Cognitive Neuroscience

- Perception: Proprioception
  - self internal senses
    - Allow the auto perception (body)
      - Signalization of malfunctions
      - Self reference
      - Vital character

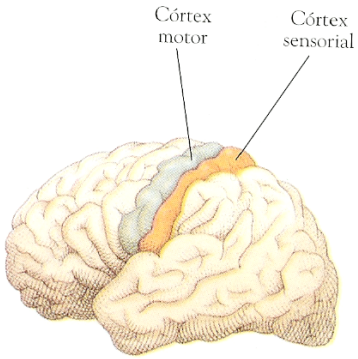
Cognitive Neuroscience

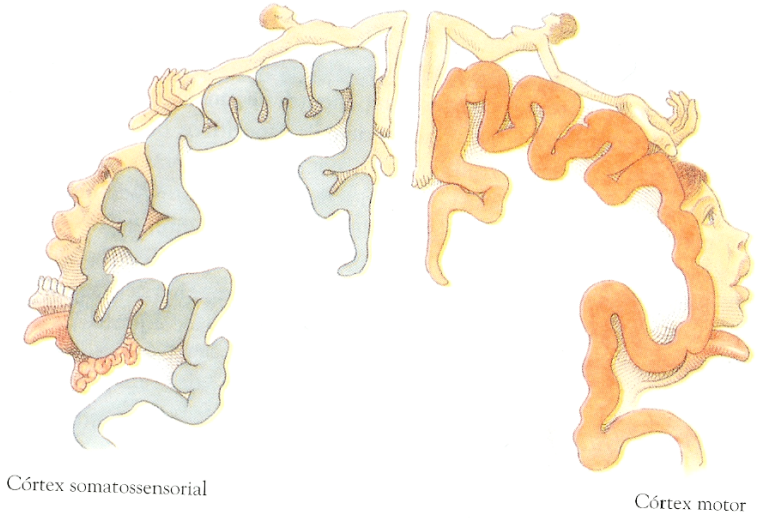
- Perception: Tact / Touch
  - Felling by touching
  - Survival importance
  - Handled at somatosensory cortex (parietal)
  - Boundary to the motor cortex (frontal) - neighbors



Cognitive Neuroscience

- Perception: Tact / Touch
  - Less sophisticate
  - But accurate
    - Mental Maps – Homunculus
    - Different levels of sensibility





Cognitive Neuroscience

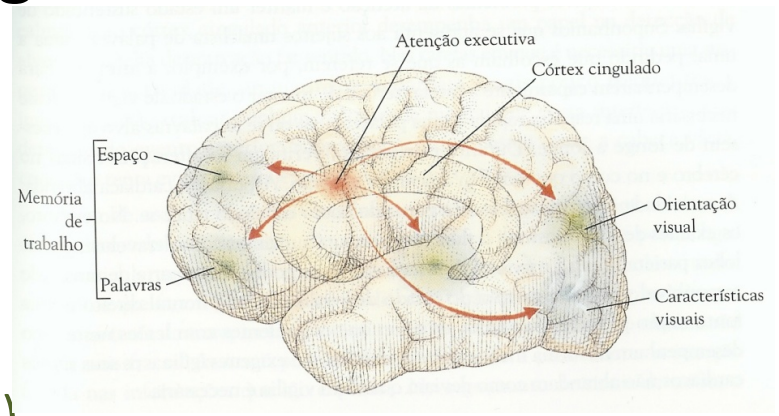
- Perception: Odor e Taste
  - Primitive
    - Require contact
    - But highly accurate
  - Allow sensing of substances in the surroundings
    - Molecules / substances
    - Survival importance
  - Sensed by nose & mouth/tong
  - Handled by olfactory bulb
    - not part of the cortex

Section 3.3

- Cognitive Neuroscience – Perception
  - Audition
  - Vision

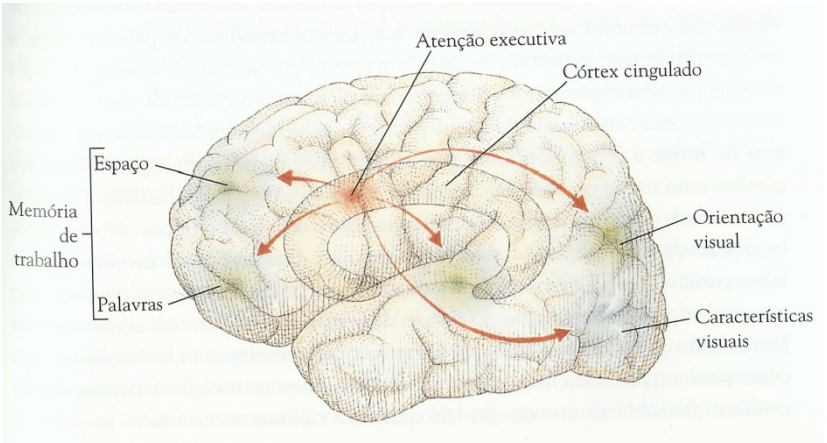
Cognitive Neuroscience

- Perception: Audition / Hearing
  - Sound processing
    - Sound recognition
      - Music / Environmental Noise
      - Signals (language)
    - Environment recognition (spatial sound – source / position)
  - Complementary to vision
    - Not so precise (less accurate)
    - But not confined to view field
    - What, Where, When
  - Handled by auditory cortex (parietal)



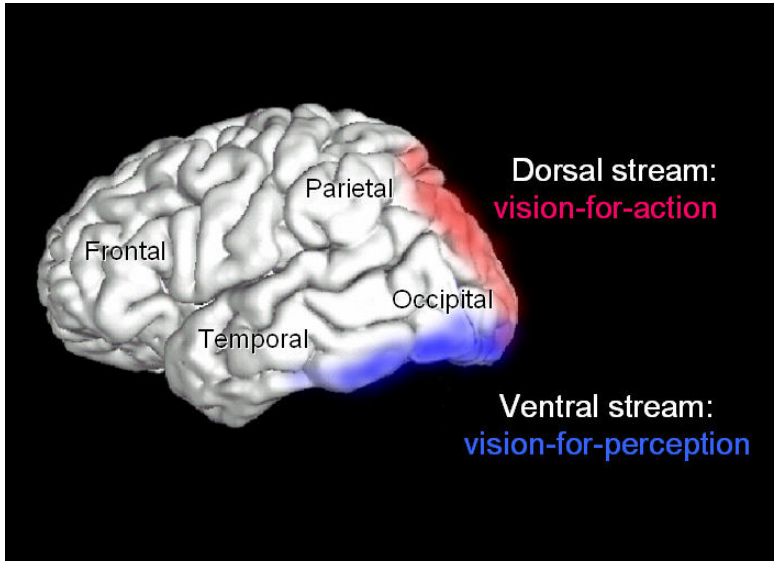
Cognitive Neuroscience

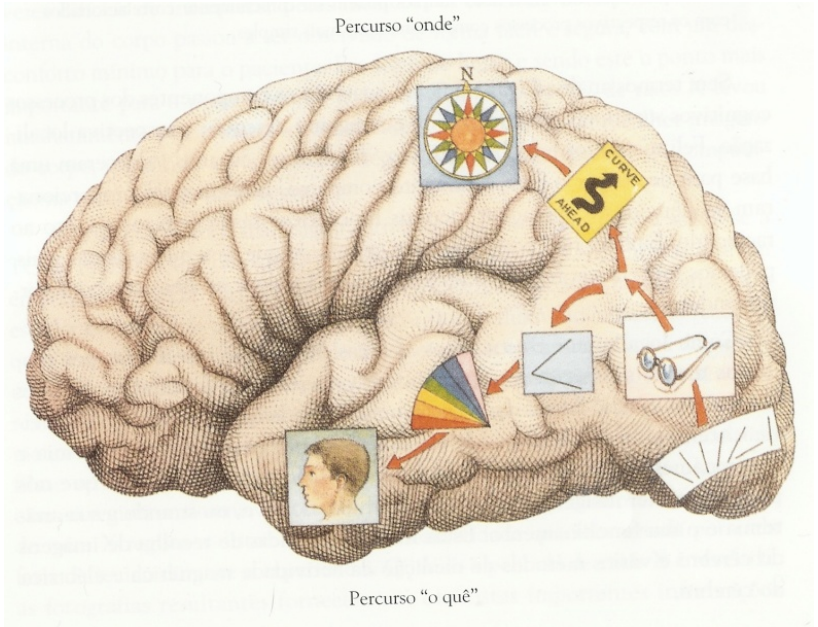
- Perception: Audition / Hearing
  - Language Interpretation
    - Comprehension
    - Wernick area
  - Inter-relation with language speaking
    - Broca area



Cognitive Neuroscience

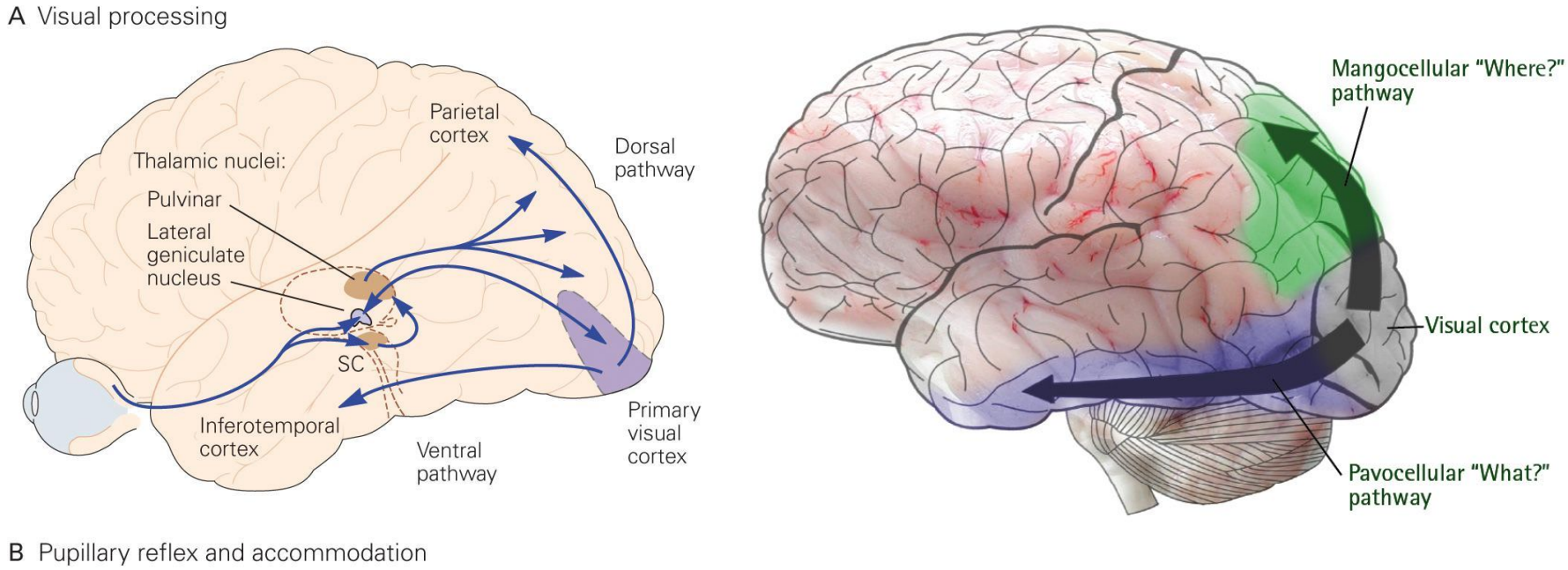
- Perception: Vision
  - The multi-sensing feature of the visual system
    - Processing follows different paths / circuits
      - Dorsal stream (where: action)
      - Ventral stream (what: perception)





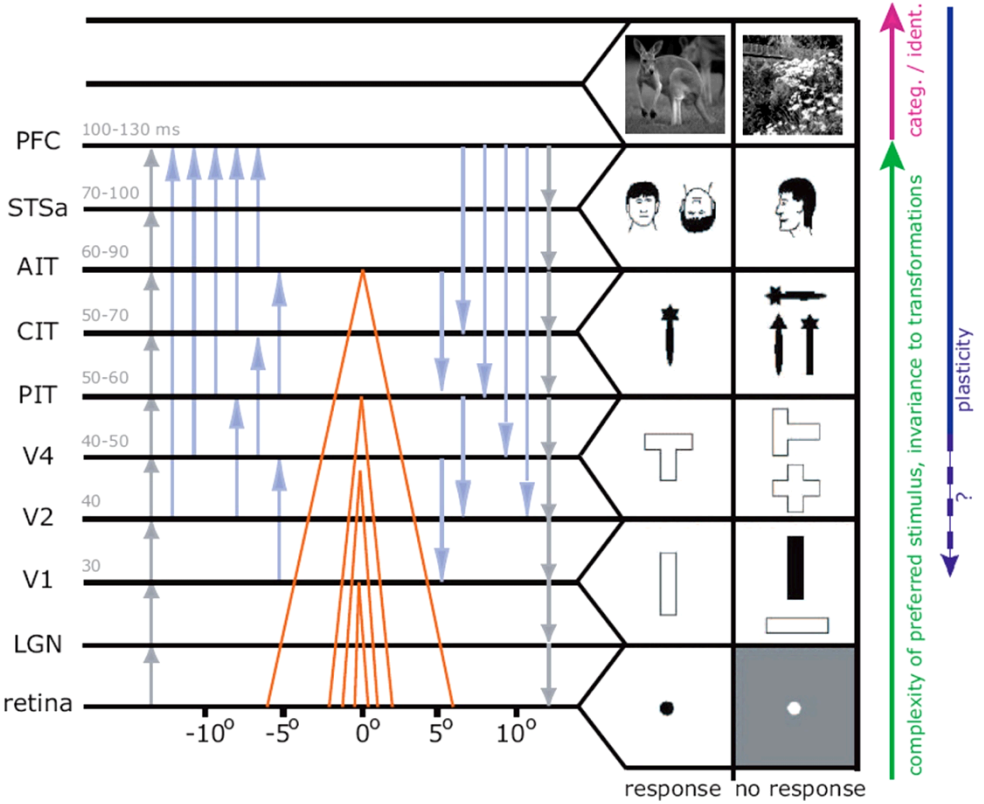
Cognitive Neuroscience

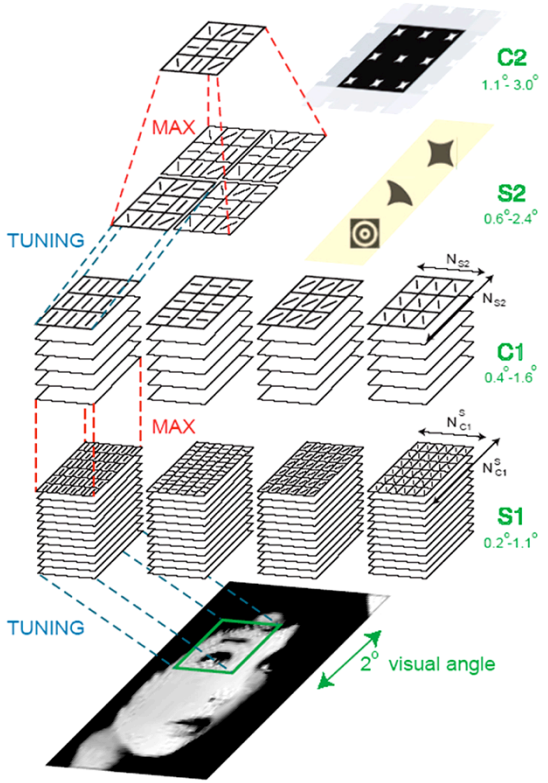
- Perception: Vision
  - The multi-sensing feature of the visual system
    - Processing follows different paths / circuits
      - What (ventral) & Where (dorsal) pathways



Cognitive Neuroscience

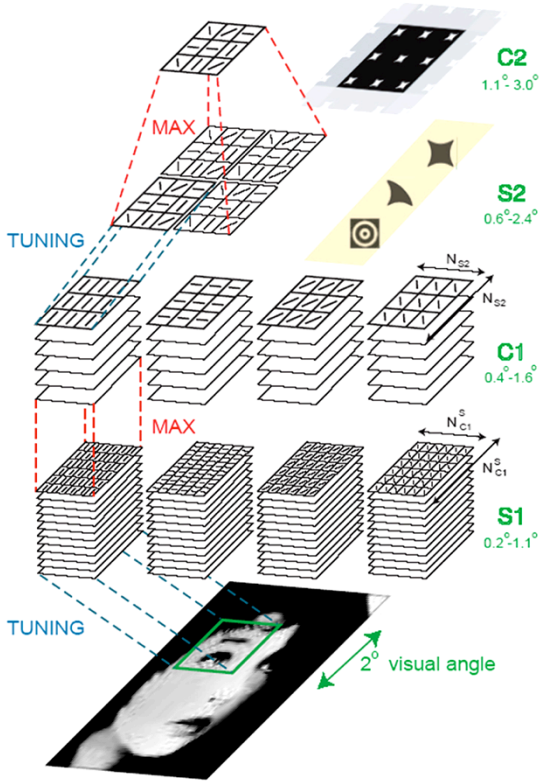
- Perception
  - processing level – concret to abstract





Cognitive Neuroscience

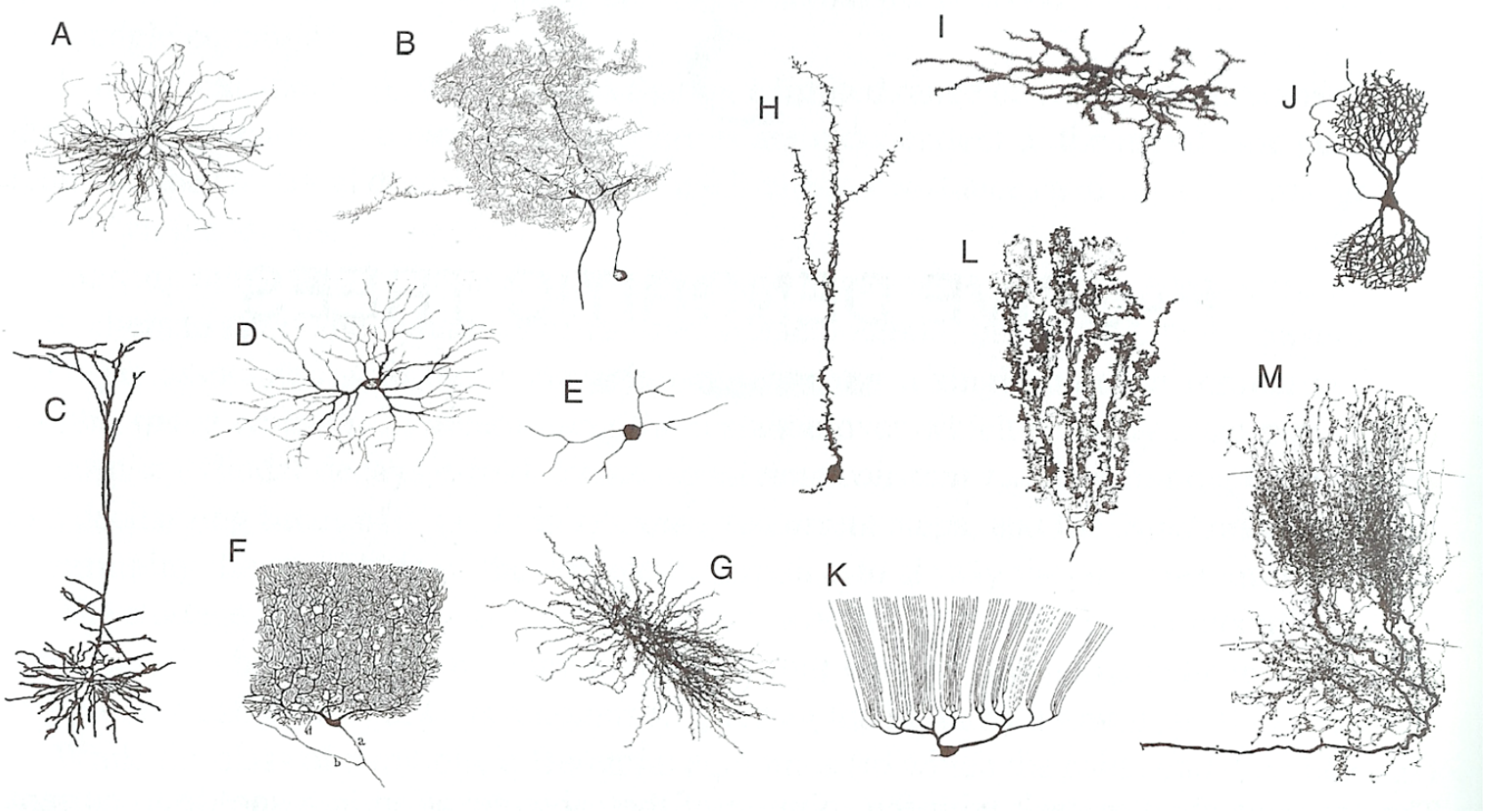
- Perception
  - processing level – concret to abstract
  - Structurally and functionally close to
    - Convolutional Neural Network
    - Deep Learning



Section 4

- Neuroscience – Micro Scale (cell: neuron)
  - Neuron structure
  - Signal flow
  - Neurotransmitter

Neuroscience – micro scale: Neurons

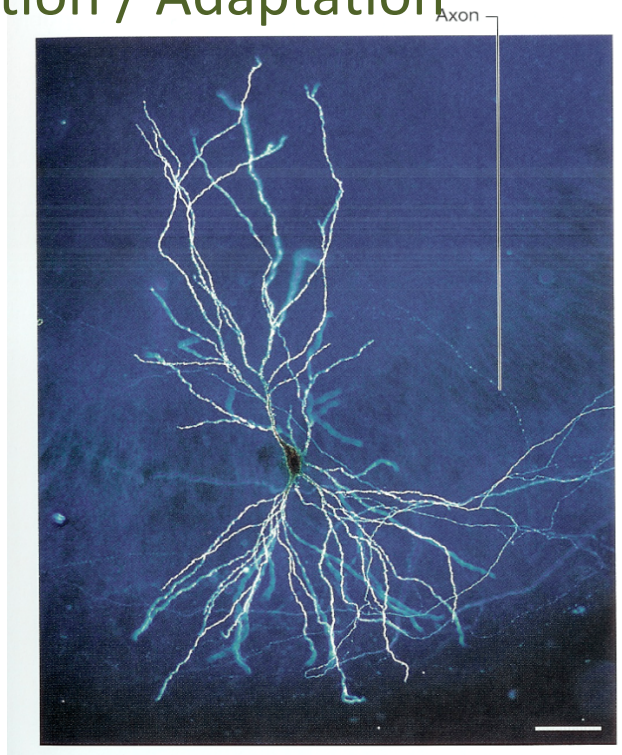


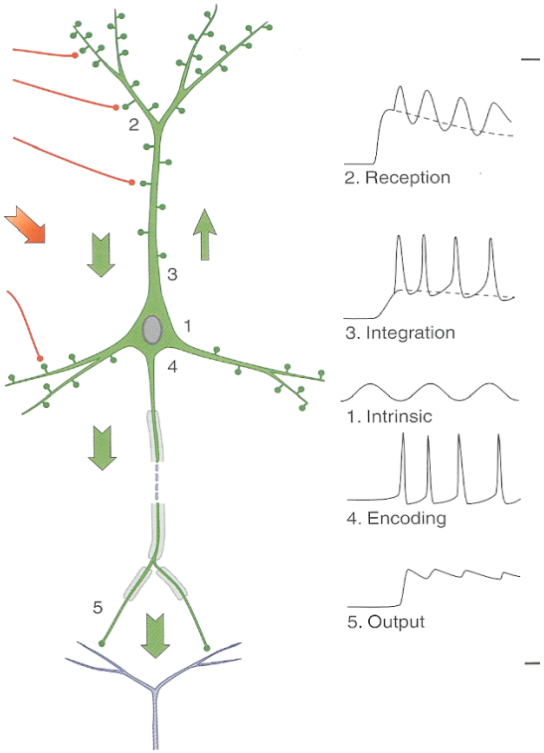
Neuroscience – micro scale: Neurons

- Neuron level
  - Dendritic tree – input
    - Combine multiple influences/contributions from previous neurons (modulation effects)
  - Soma – kernel
    - Sum and threshold – produces the action potential pulse
  - Axon – propagation
    - Propagates the signal to further neurons
  - Synapse – connection between two neurons
    - Neuro transmitters and receptors (different types and properties)
    - Modulation effects

Neuroscience – micro scale: Neurons

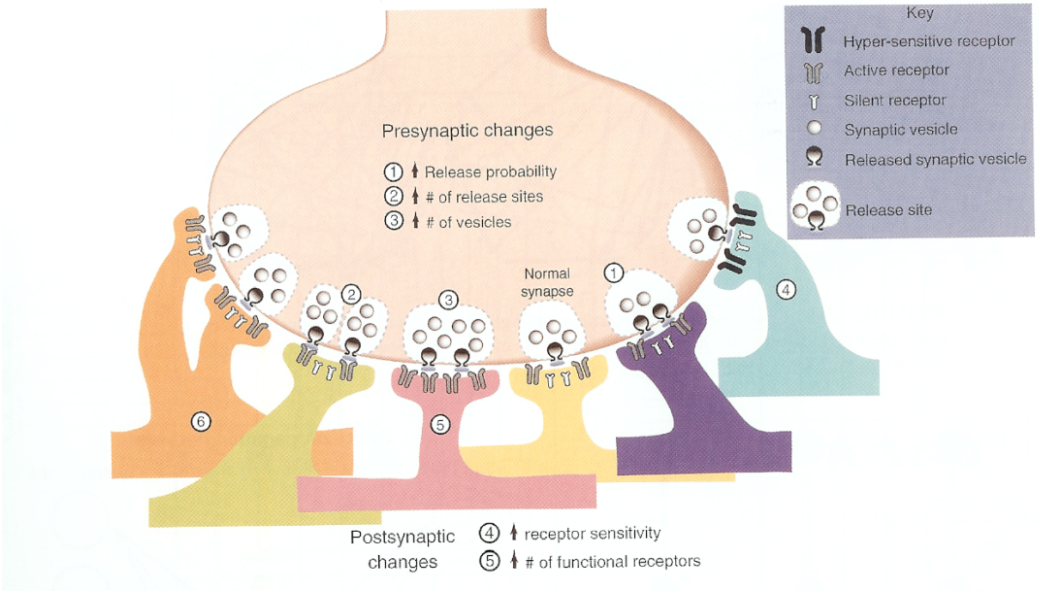
- Signal processing / propagation / codification
  - Morph-electro-tonic principle
    - Modulation / Adaptation

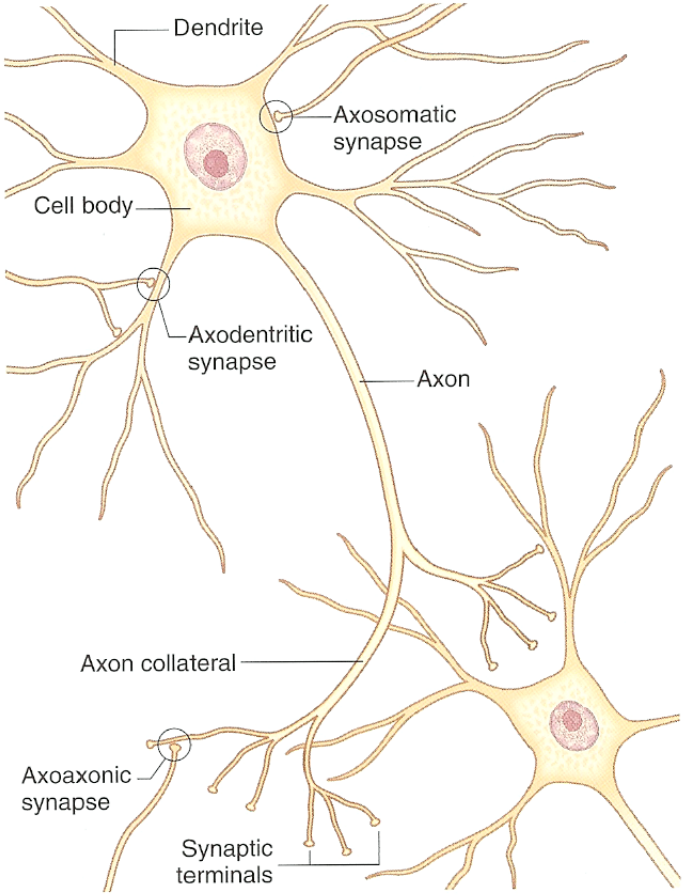




Neuroscience – micro scale: Neurons

- Synapsis
- Neurotransmitters & receivers





Cognitive Neuroscience

- Most medicine for neuroses acts on balancing neurotransmitters
  - Anxiety
  - Depression
  - Attention

- By acting on the way signals are transmitted and processed in the neuronal tissue

Section 5

- Neuroscience – Memory
  - Types
  - Categories

Memory functional aspects

- Memory Types
  - Long-term memory
    - Days to life-long
  - Short-term memory
    - Minutes to days
  - Working memory
    - Seconds to minutes

Memory functional aspects

- Memory Categories
  - Declarative or Explicit memory
    - Episodic memory
      - self experiences (things we lived)
    - Semantic memory
      - world information (things we know about)
  - Procedural or implicit memory
    - Movements
  - Autobiographical memory
  - Spatial memory
    - Spatial references

Memory functional aspects

- Diversity of mechanisms, on different levels
  - Synapses
    - Reinforcement learning
      - strength of synaptic connections
  - Structural changes
    - Neuron
      - Branches / Connections
  - Systemic
    - Activation of multiple clusters
      - resonance between cell pools
  - Circuits

Memory and representation

- Representation in memory
  - Functional regions versus holographic brain
  - Feature maps
  - Hierarchical organization of feature maps
    - *"Grandmother* cell"

Coffee break

10 minutes