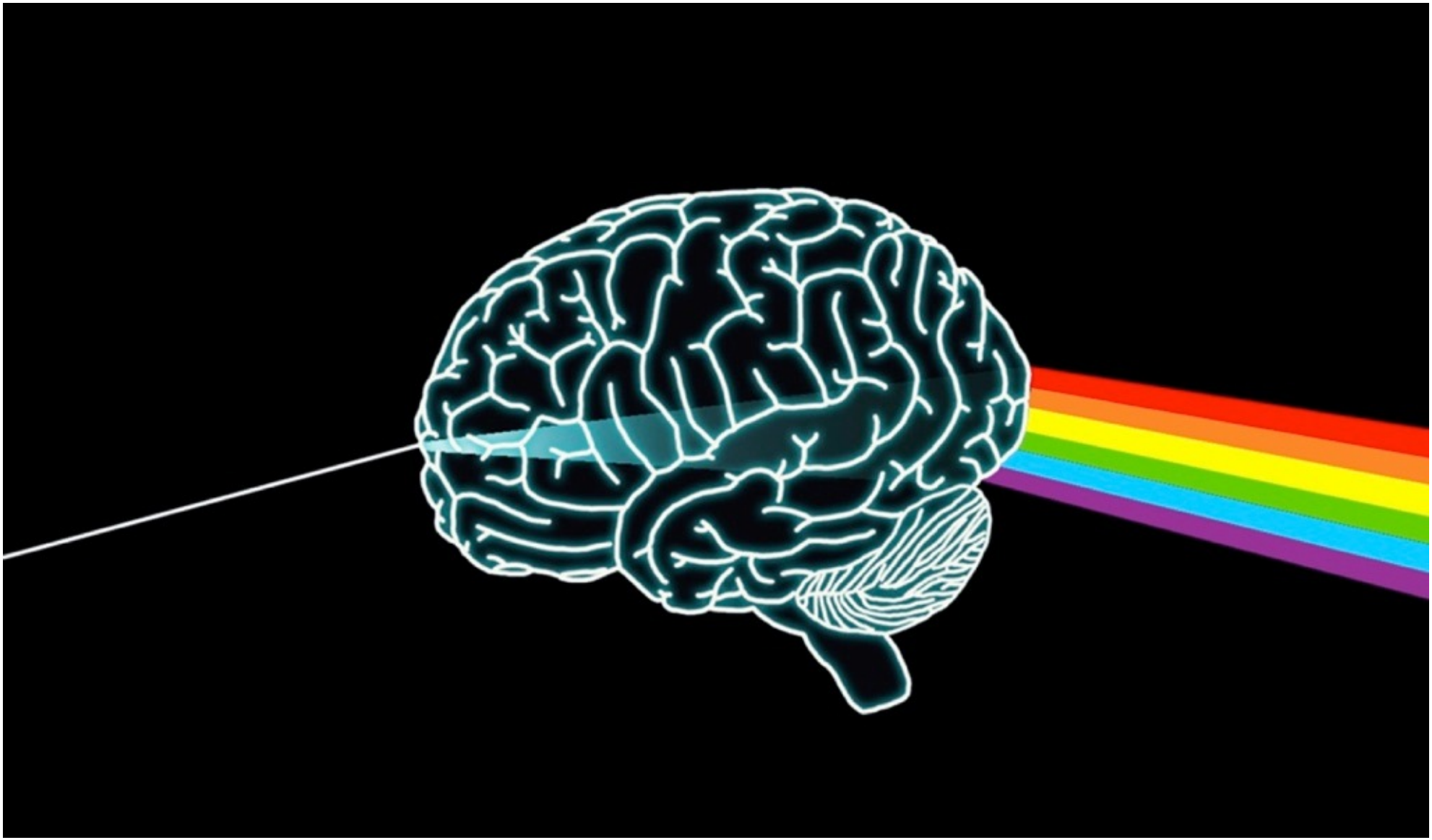
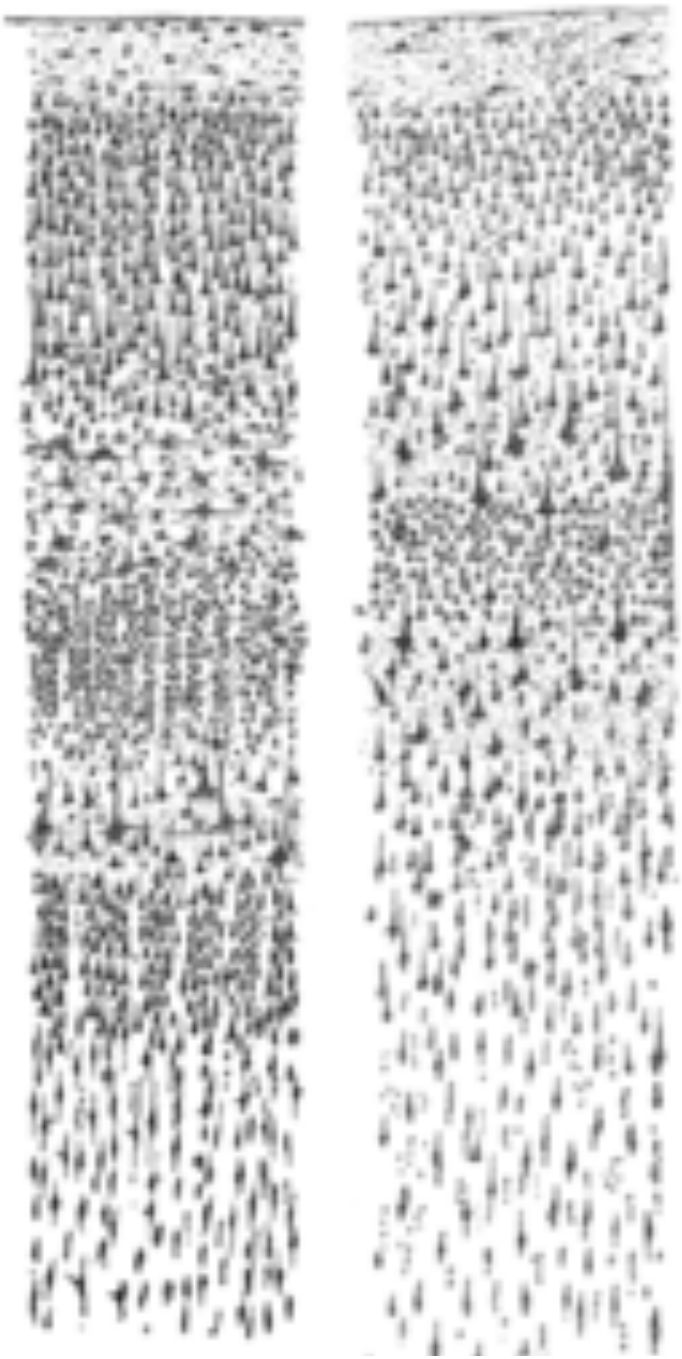
CORTICAL ORGANIZATION



Sensory (Visual)

Motor



Neocortical layers:

Layer 1 - “molecular”
Interhemispheric cortico-cortical afferents

Layer 2 - “external granular”
Interhemispheric cortico-cortical afferents

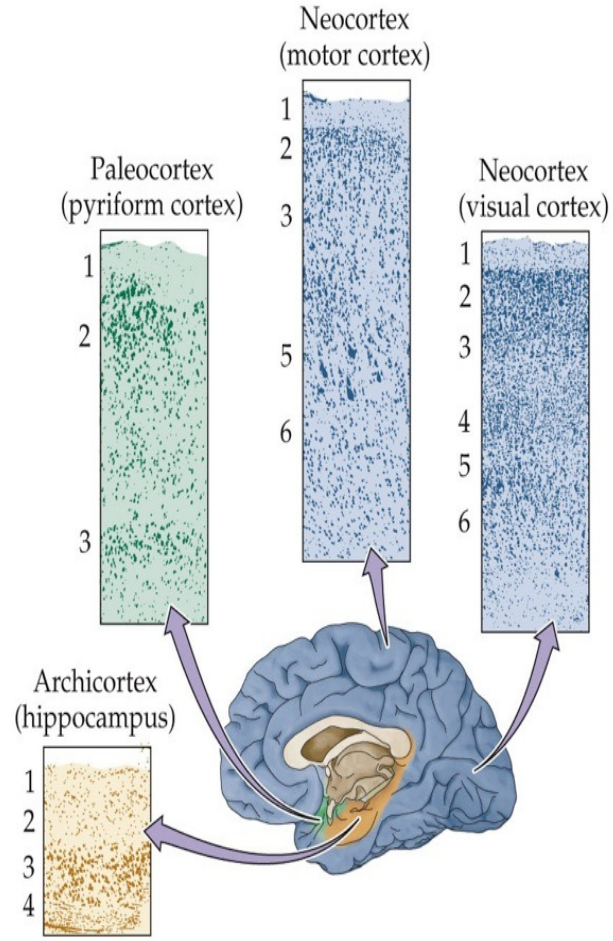
Layer 3 - “external pyramidal”
Interhemispheric cortico-cortical afferents and efferents

Layer 4 - “internal granular”
Target of thalamocortical afferents
(Little to none in motor cortex)

Layer 5 - “internal pyramidal”
Cortico-subcortical / spinal efferents

Layer 6 - “polymorphic”
Reciprocal “corticothalamic efferents

Layered organization of cortex:



Paleocortex – 3 layers
hippocampal formation / ventral & medial cortex
closest to brainstem

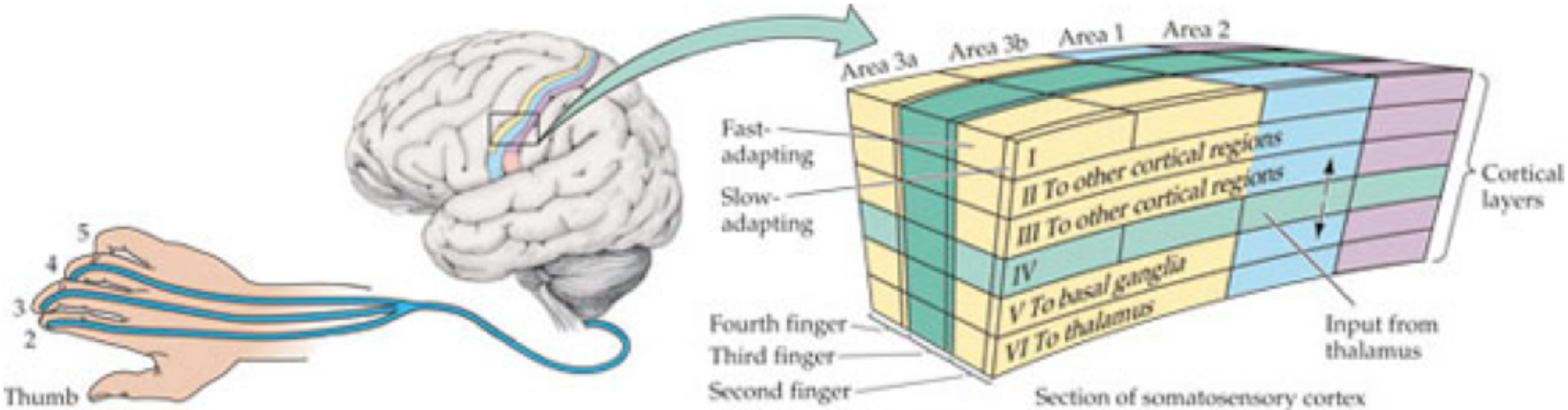
Archicortex – 3-4 layers
hippocampal formation / amygdala

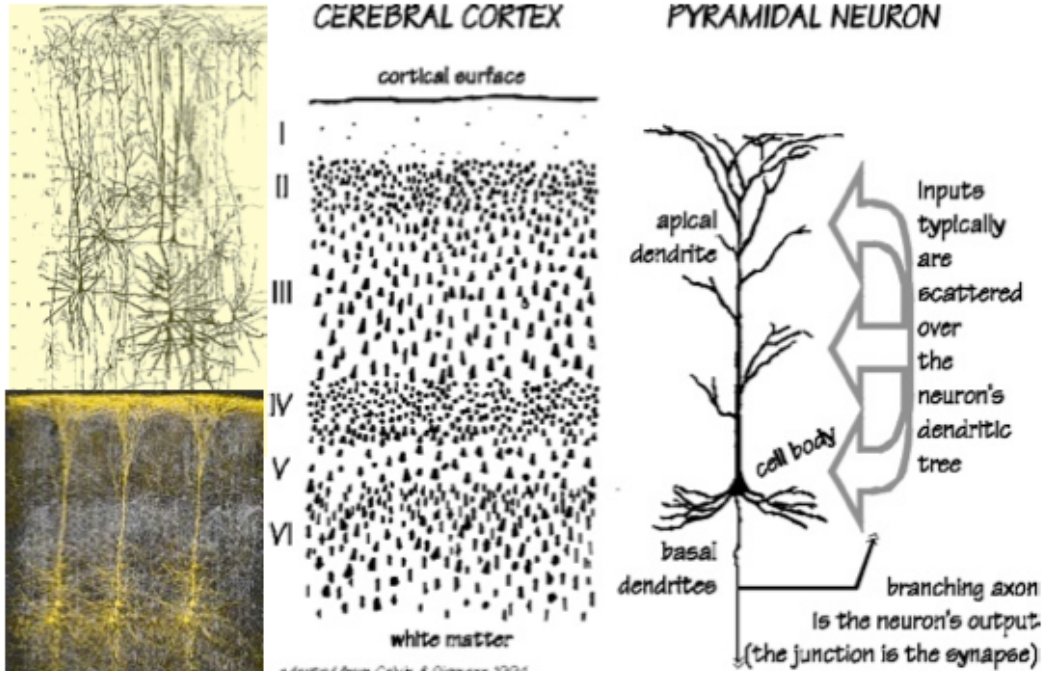
Neocortex – 6 layers
more layers > more complex processing
cytoarchitectonically distinct regions
functionally distinct
Across all neocortical areas:

- each layer has a primary source of inputs & primary output targets
- columnar organization (connections)
- lateral connections
  - between local columns and other cortical areas

Functional Cortical Units

- individual cortical neurons arranged into *columns* and *layers*



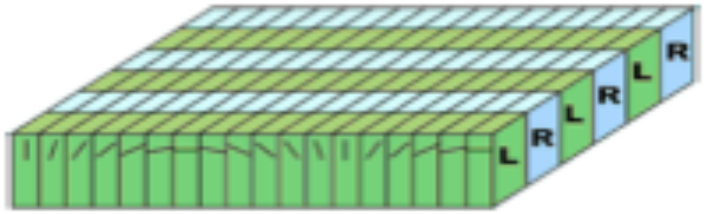


FUNCTIONAL CORTICAL UNITS

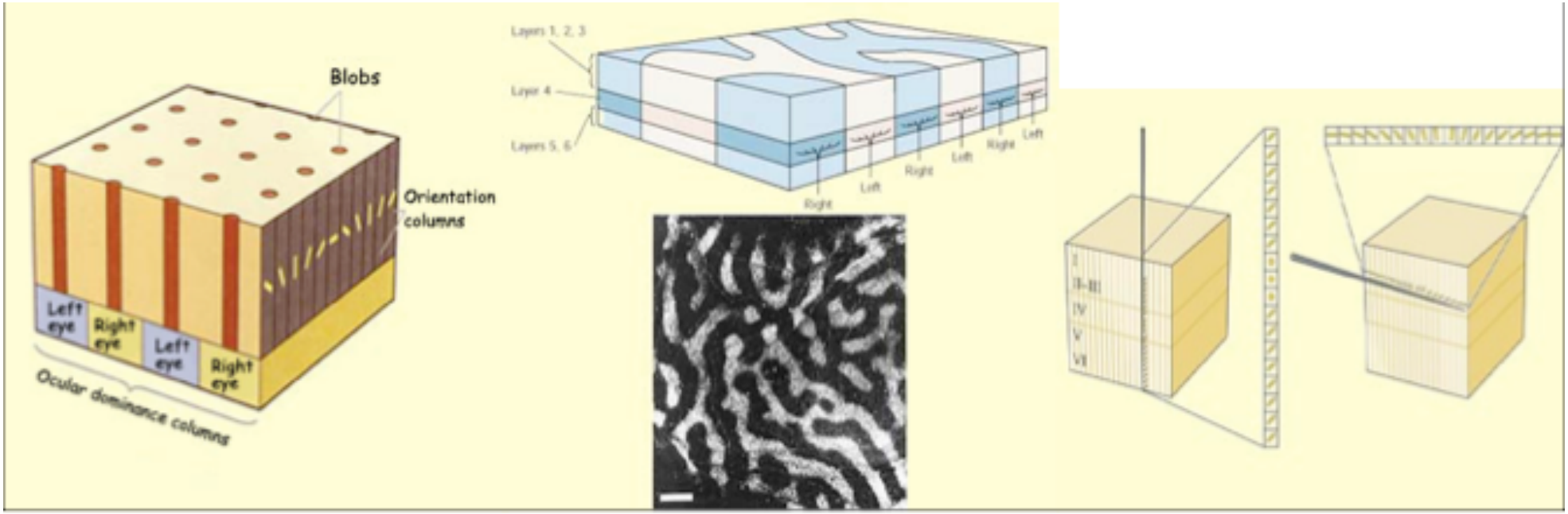
- Primary Visual Cortex (V1) - 5th order +

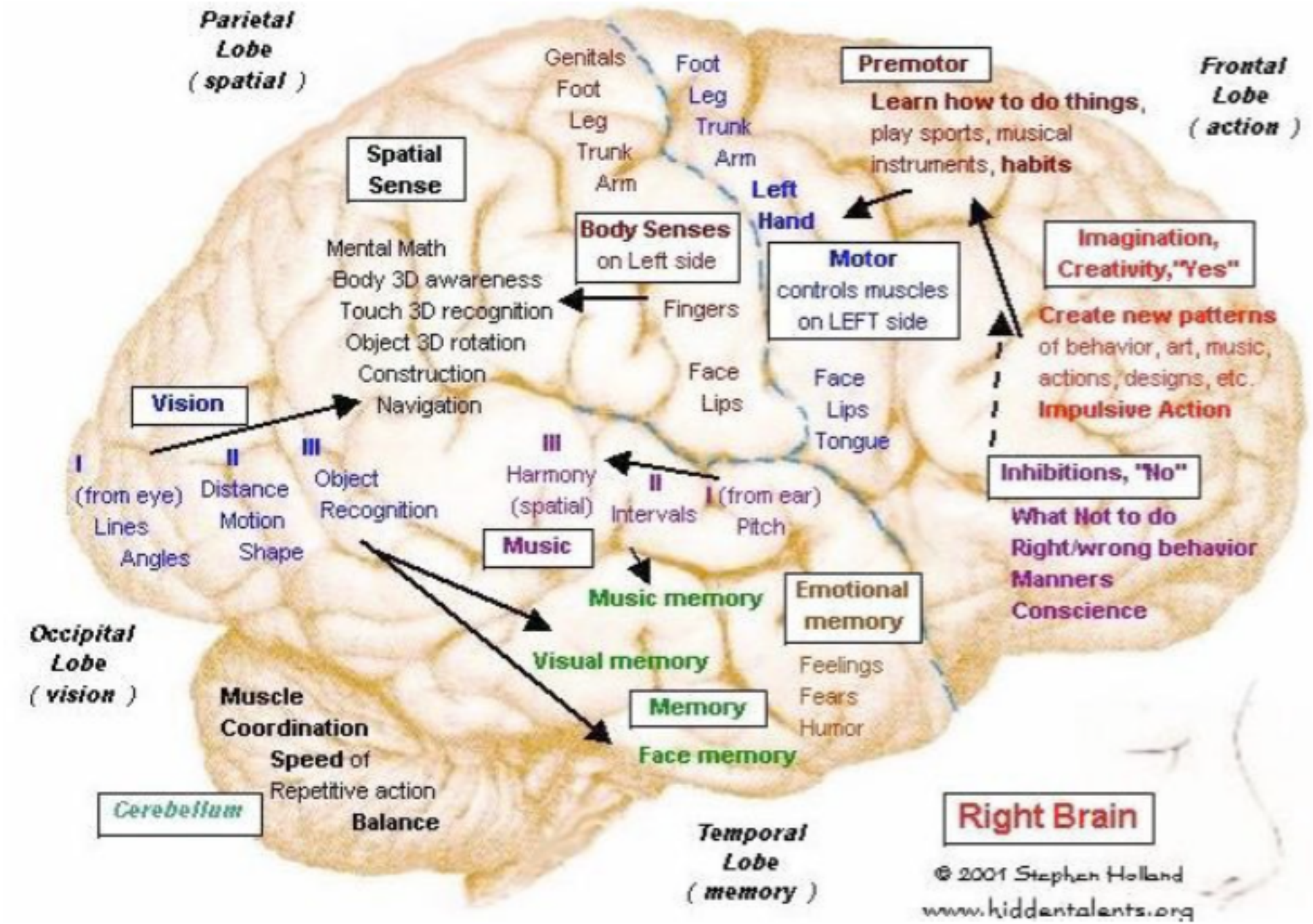
  individual columns arranged into *microcircuits* of ~1 mm sq *hypercolumns*

  - Vision:
    - ocular dominance columns (right / left eyes)
    - orientation columns
    - "color" blob



  - responses of *individual* neurons are probabilistic (and relatively unimportant)




Parietal Lobe (spatial)
Genitals
Foot
Leg
Trunk
Arm
Foot
Leg
Trunk
Arm
Premotor
Learn how to do things, play sports, musical instruments, habits
Frontal Lobe (action)
Spatial Sense
Left Hand
Body Senses on Left side
Mental Math
Body 3D awareness
Touch 3D recognition
Object 3D rotation
Construction
Navigation
Fingers
Motor controls muscles on LEFT side
Imagination, Creativity, "Yes"
Create new patterns of behavior, art, music, actions, designs, etc.
Impulsive Action
Face
Lips
Face
Lips
Tongue
Vision
I (from eye) Lines Angles
II Distance Motion Shape
III Object Recognition
III Harmony (spatial)
II Intervals
I (from ear) Pitch
Music
Inhibitions, "No"
What Not to do
Right/wrong behavior
Manners
Conscience
Music memory
Emotional memory
Occipital Lobe (vision)
Visual memory
Feelings
Fears
Humor
Memory
Face memory
Muscle Coordination
Speed of Repetitive action
Balance
Cerebellum
Temporal Lobe (memory)
Right Brain
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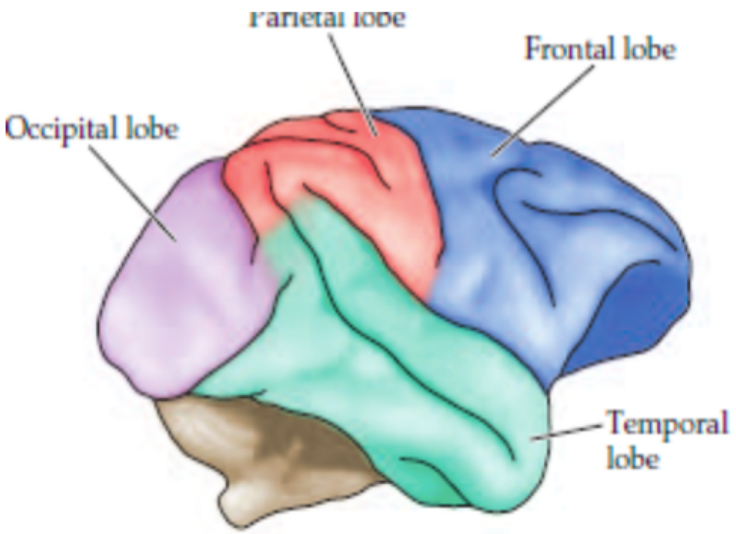
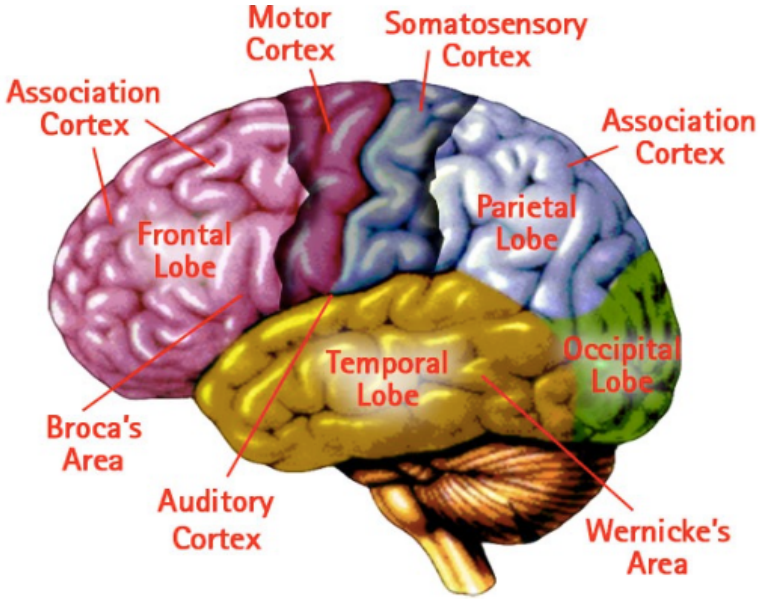
Primary sensory and motor ~1/5 of the cortex

- simple functions:
  - encoding sensory inputs
  - producing movements

Association cortex is *most* of the cortical surface

- responsible for *cognition*
- at most basic level (s-O-r), cognition requires:
  1. **attending** to a stimulus (external or internal)
  2. **identify** its significance
  3. **decide** on appropriate response



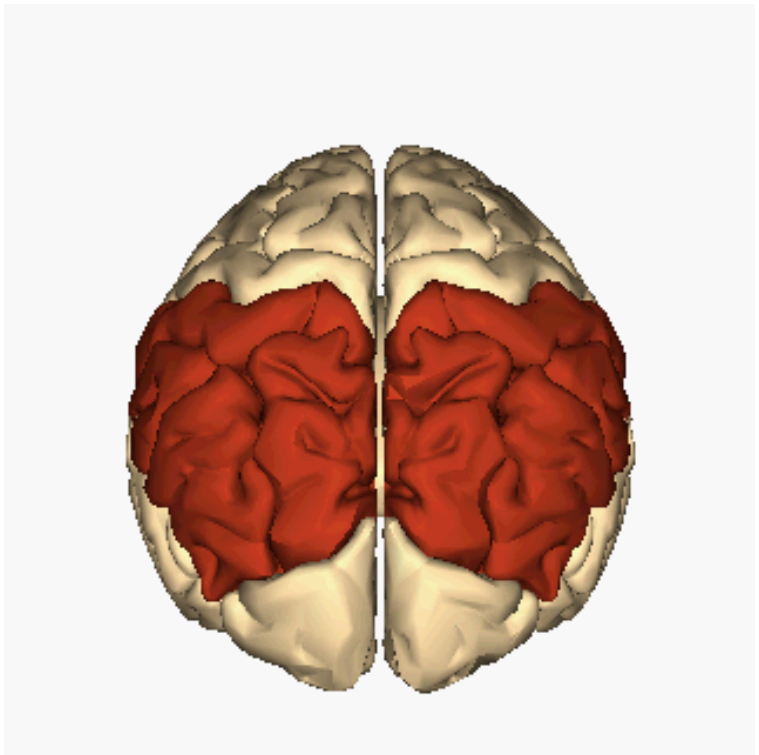


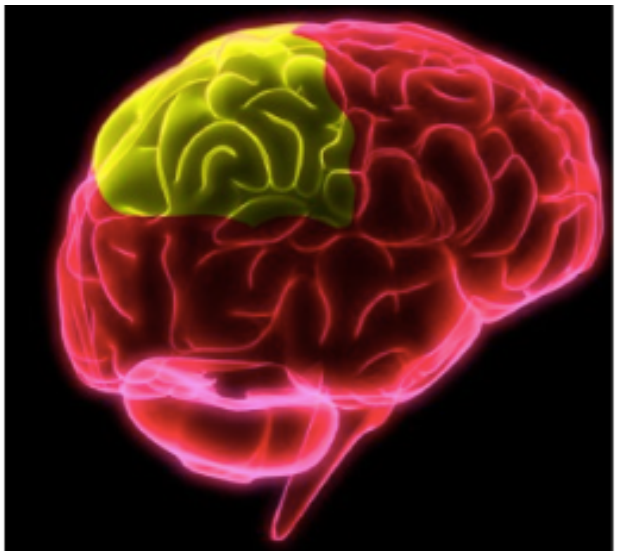
Complex brain functions are simply built from multiple smaller functions happening in parallel and in sequence

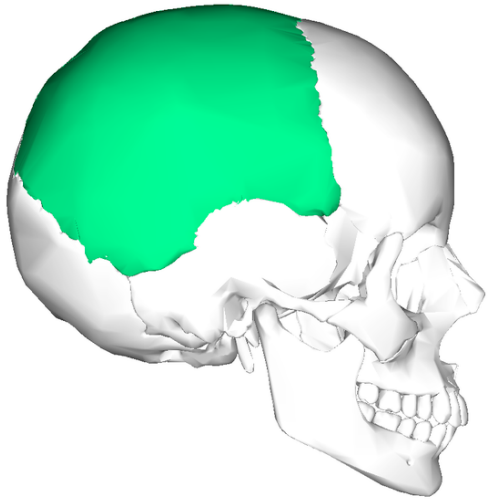
Cognitive steps in very basic Stimulus-Response

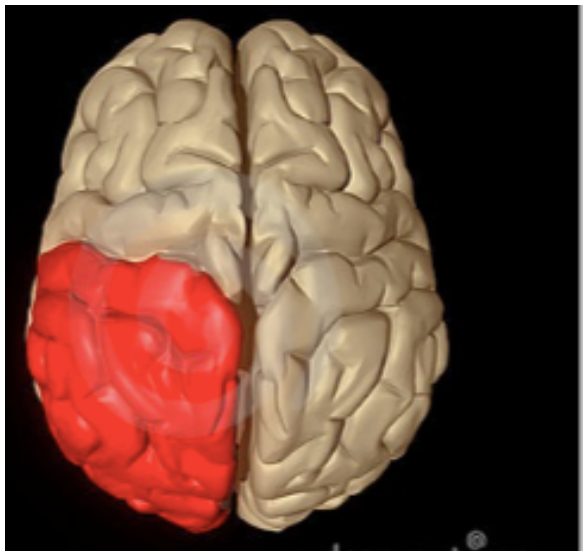
1. Attend to stimuli - parietal
2. Identify stimulus - temporal
3. Select and plan appropriate reaction - frontal

Parietal: attending to stimuli (external or internal) STEP 1



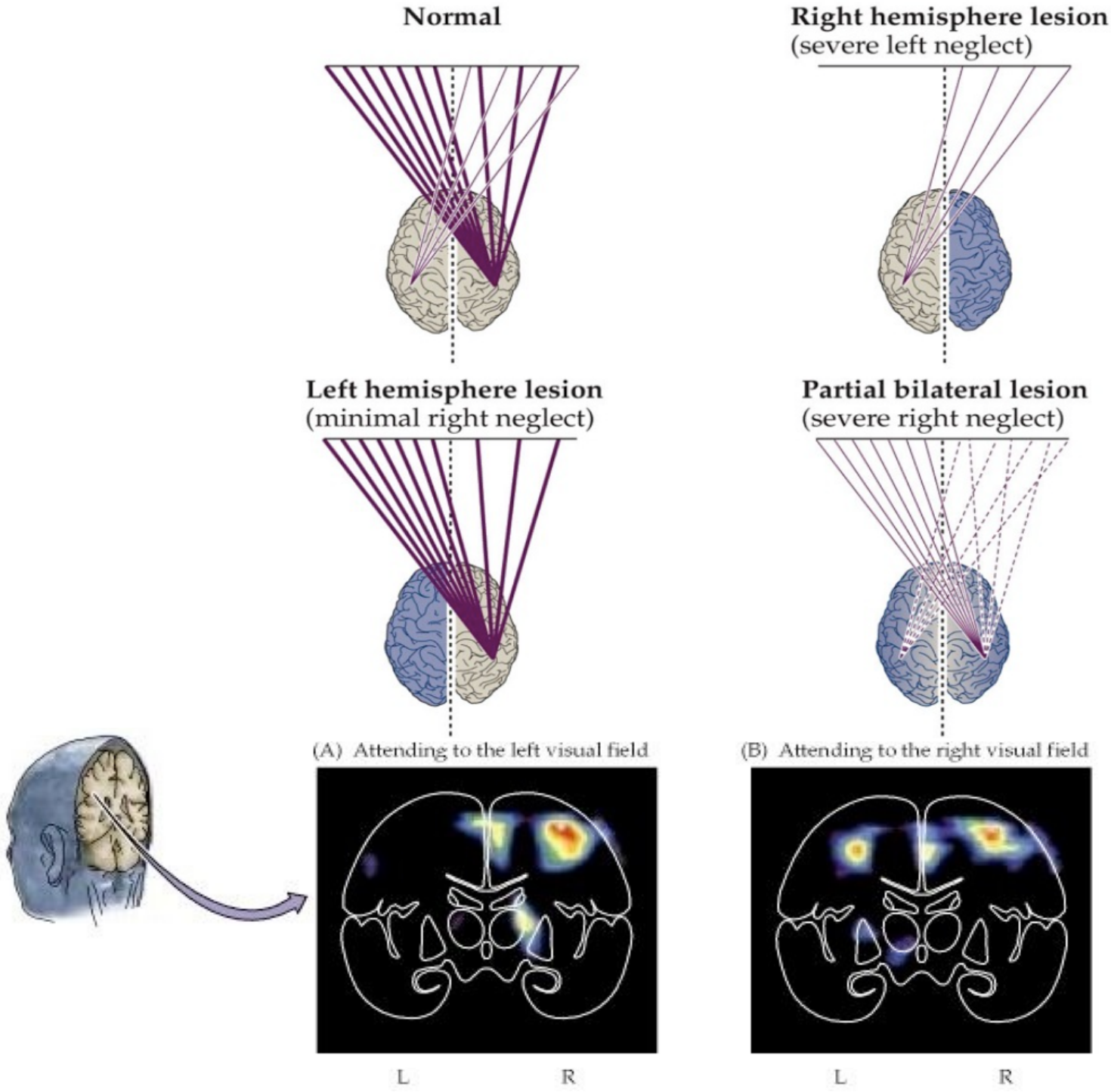






Parietal: attending to stimuli (external or internal)

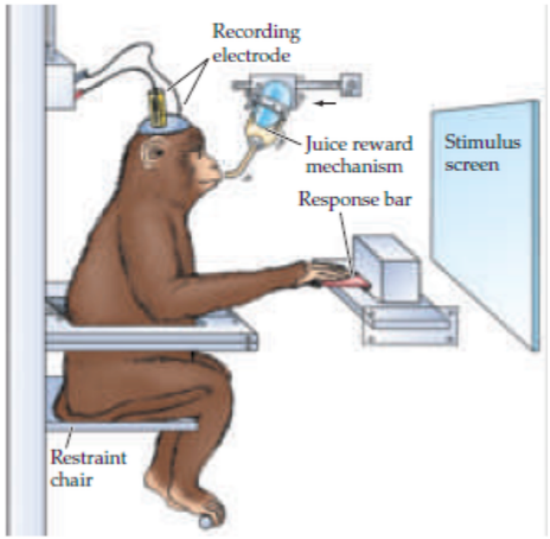
- target of the dorsal “where” visual path
  - damage leads to deficits in attention
    - Right side, inferior parietal cortex
      - contralateral neglect syndrome
        - sensory / motor (apraxia)
      - Hemispheres contribute to attention differentially
        - Left only manages attention for right side
        - Right manages attention for both sides
          - R parietal can compensate for L damage, but L cannot compensate for damage to R


Normal
Right hemisphere lesion
(severe left neglect)
Left hemisphere lesion
(minimal right neglect)
Partial bilateral lesion
(severe right neglect)
(A) Attending to the left visual field
(B) Attending to the right visual field
L
R
L
R

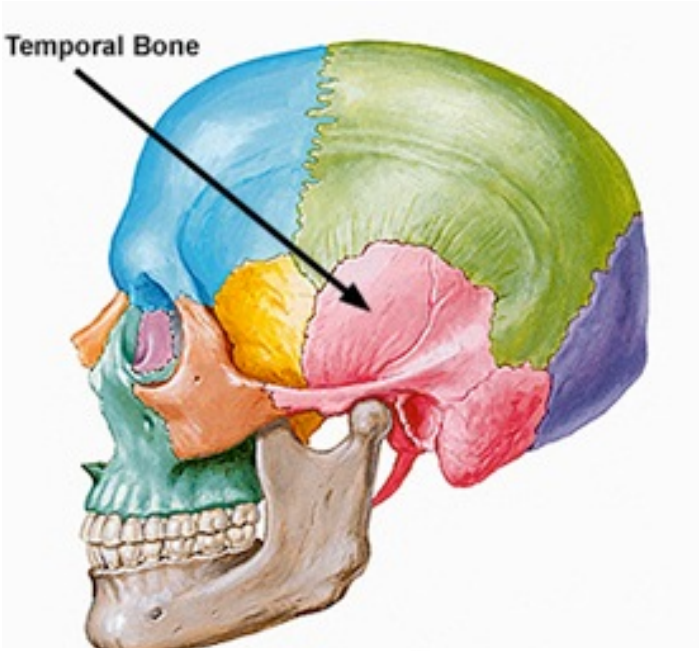
Parietal: attending to stimuli (external or internal)

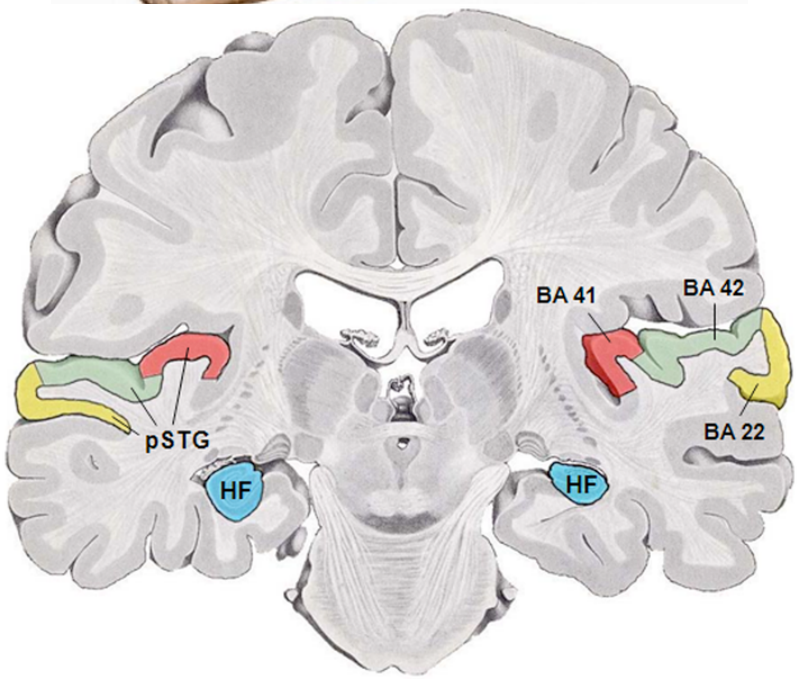
Electrophysiology of monkey brains

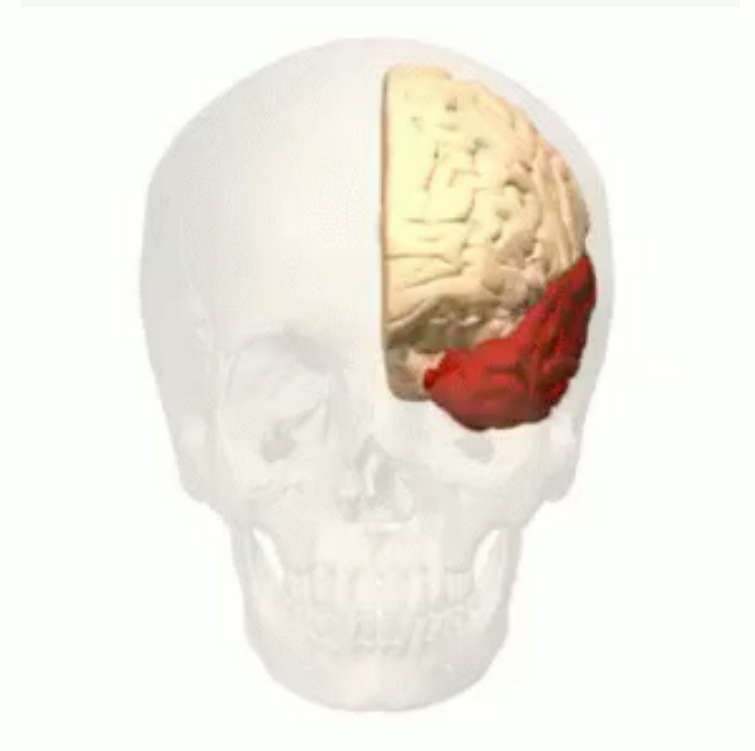
- Some parietal cortical neurons respond only when the monkey is attending to a "**meaningful**" stimulus
  - Firing rate indicates behavioral importance
- Outputs <u>from</u> parietal (and frontal) association areas <u>to</u> primary sensory cortices
  - Primary processing is "enhanced" for attended stimuli and attenuated for ignored stimuli



Temporal: identifying stimuli STEP 2







Temporal: identifying stimuli

inferior portion (IT) is responsible for “recognition”

target of the ventral “what” visual path

adjacent to auditory and “language” cortices in the superior temporal lobe

damage to Right IT usually leads to:

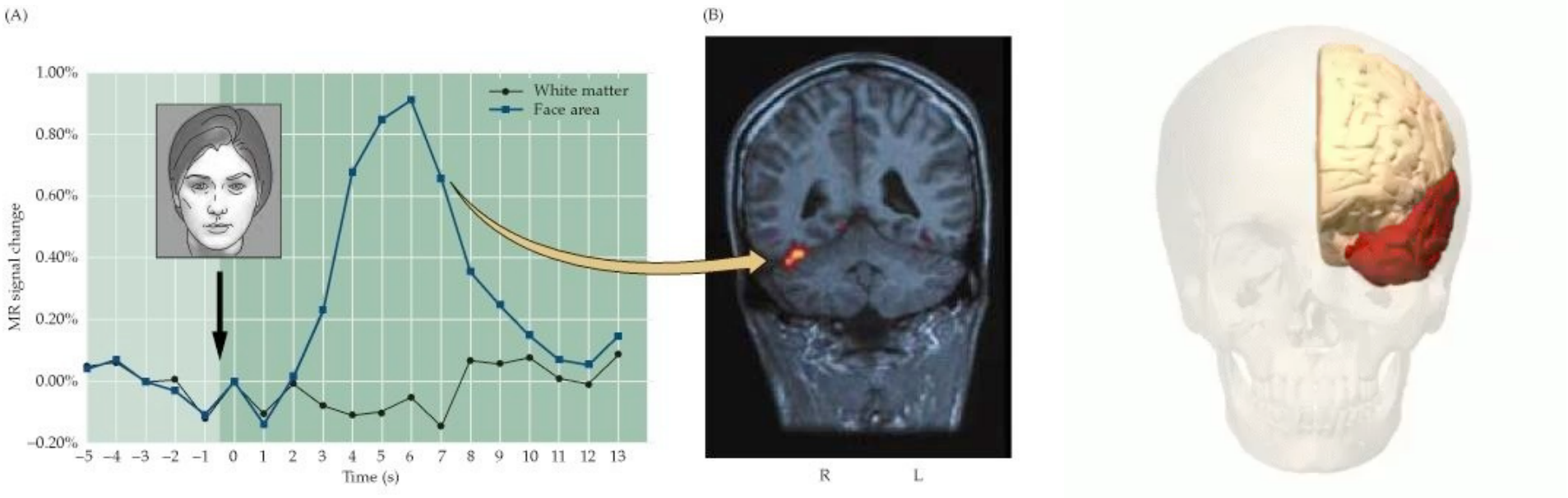
agnosias - difficulty with recognizing, identifying and naming categories of objects

prosopagnosia – agnosia for faces

not neglect – can describe what they see, just can’t identify it or name it

identify people using other characteristics

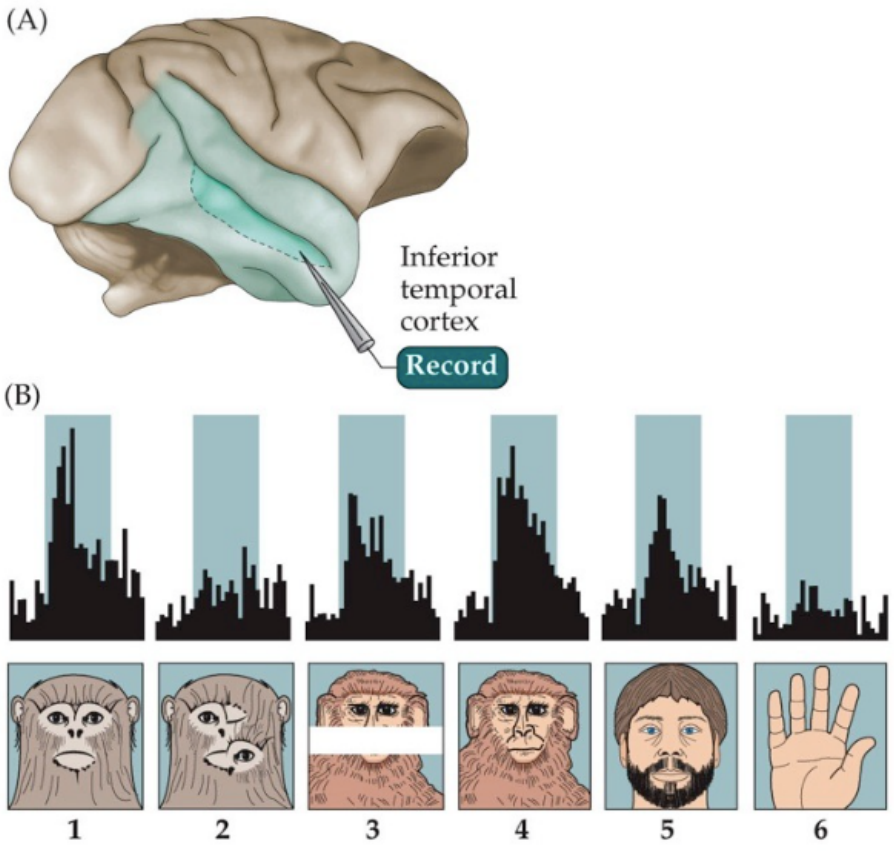
damage to Left IT (especially more dorsal / lateral) usually leads to language problems

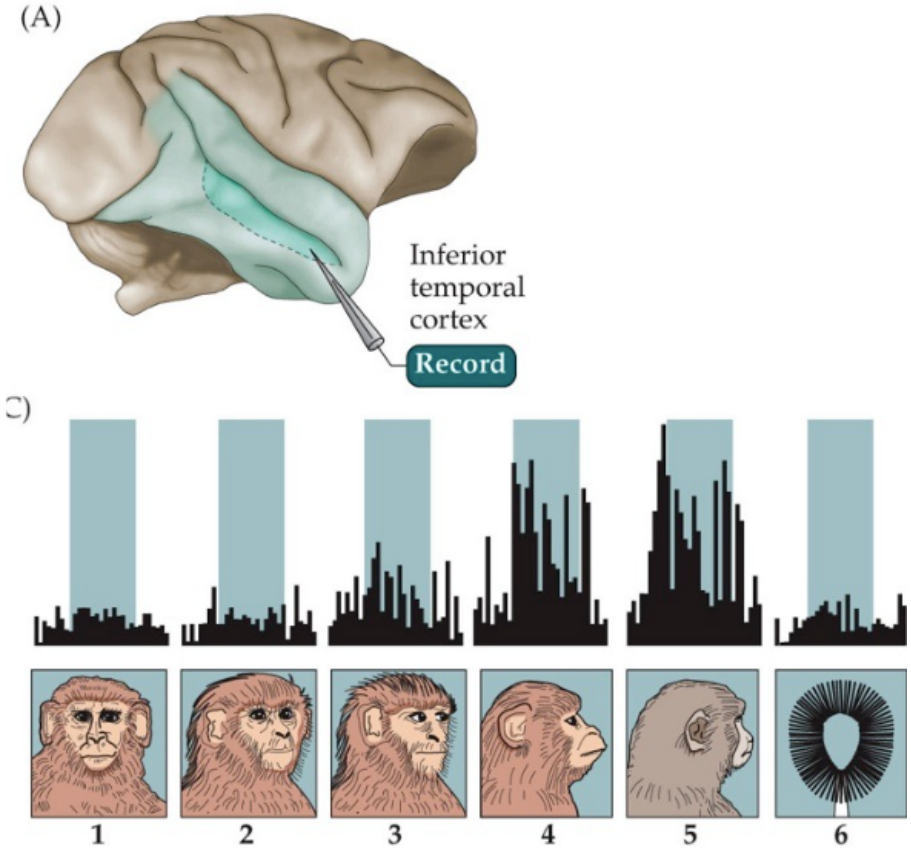


Temporal: identifying stimuli

Electrophysiology of monkey brains

- Some IT cortical neurons respond only when the monkey is seeing a monkey face
  - Some respond only to specific facial orientations

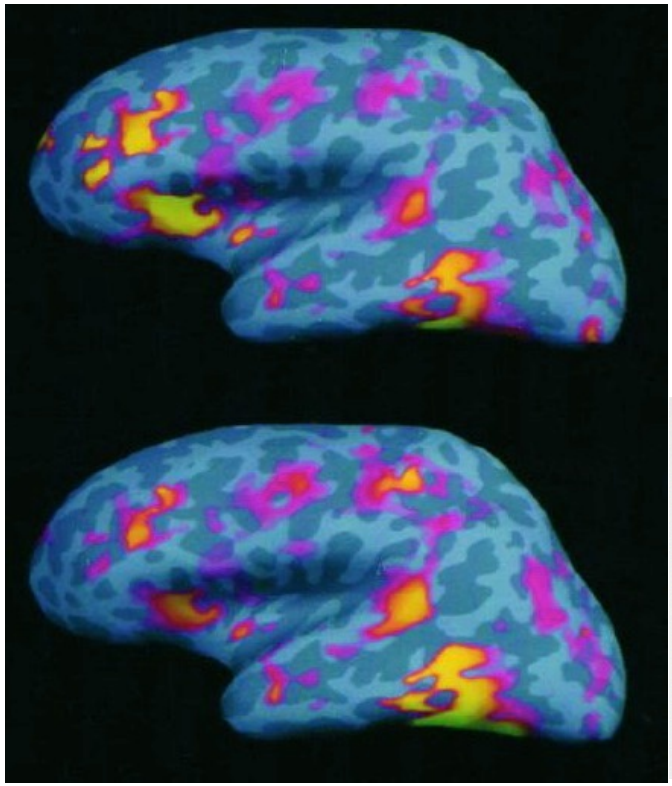




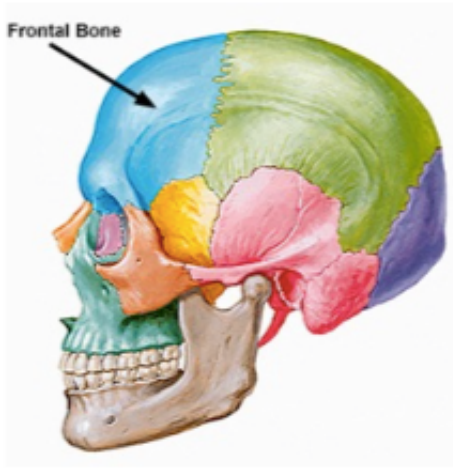
Temporal: identifying stimuli

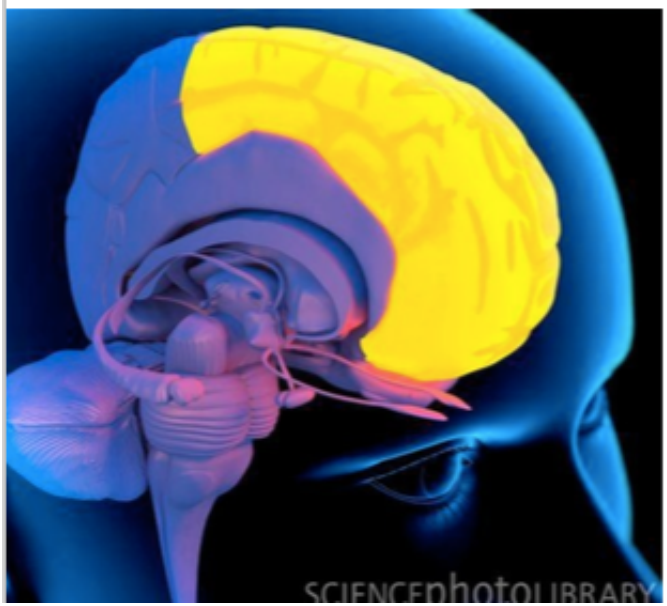
Individual **neurons** probably don't respond only to specific faces (no "grandmother cell")

Populations (columns) analyze (sense) various features of the face and the graded "population code" (specific spatiotemporal pattern of the local network) is recognized (perceived) as "grandma"



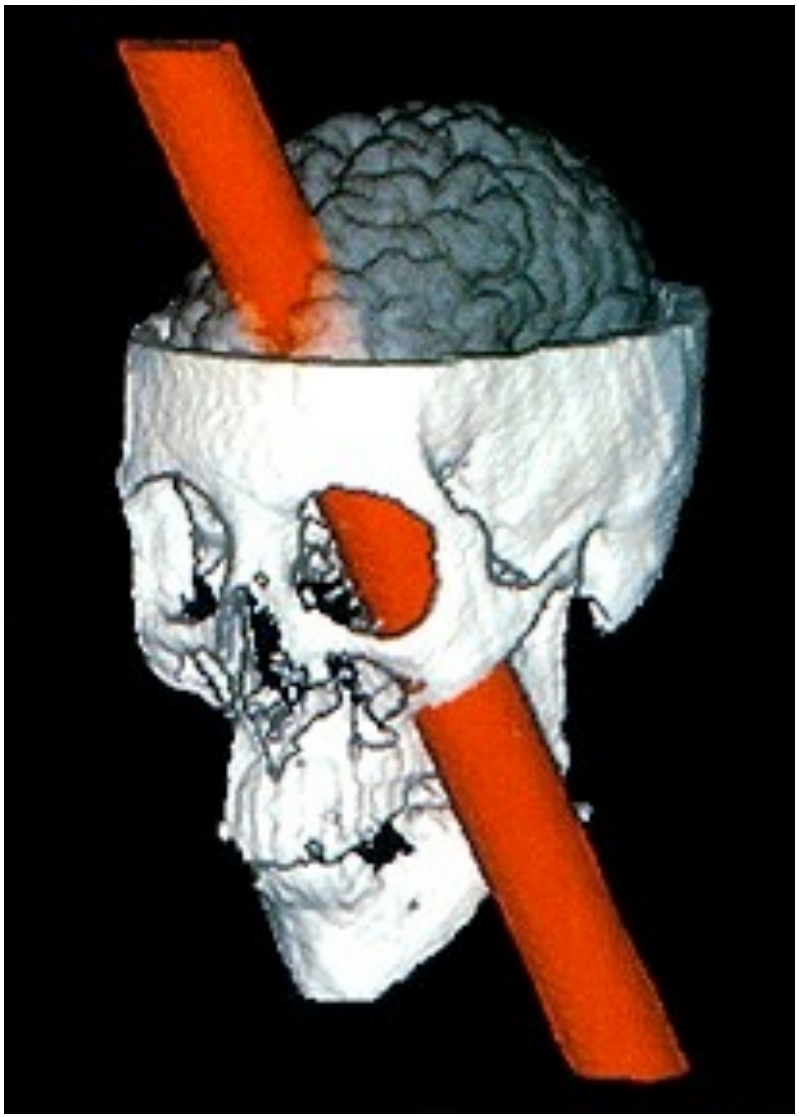
Frontal: selecting and planning appropriate behavioral responses
STEP 3





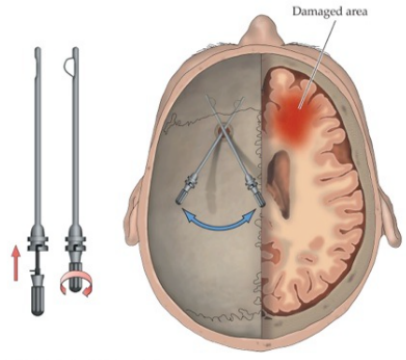
Frontal: selecting and planning appropriate behavioral responses

- matching current behavior to present and future demands
- bilateral lesions often dramatically change a person's "character"
    - Phineas Gage
        - impaired restraint
        - disordered thought
        - perseveration
        - inability to plan for future
            - Wisconsin card sorting / Stroop

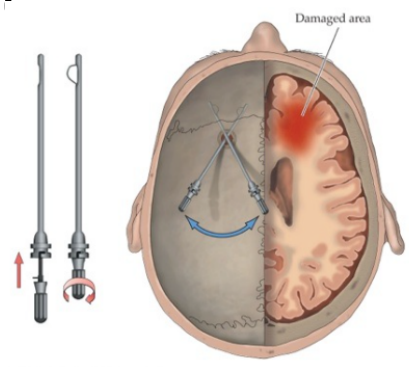


• Psychosurgery - Frontal lobotomy in 1930s-40s (pre-medication)

•1933 - research from Yale shows that bilateral lesions of aggressive chimps' prefrontal cortex mellowed them out
  • they could still do and learn stuff
• 1935 Portuguese neurologist (Moniz) heard about this and decided to try with his aggressive human patients (used trepan and alcohol)
• In the U.S., Walter Freeman performed "soul surgery" on ~4000 "patients"
    • 40% were done to "cure" homosexuality
    • at least 1 verified on a 4 year old
    • no anesthesia (ECT to knock out)



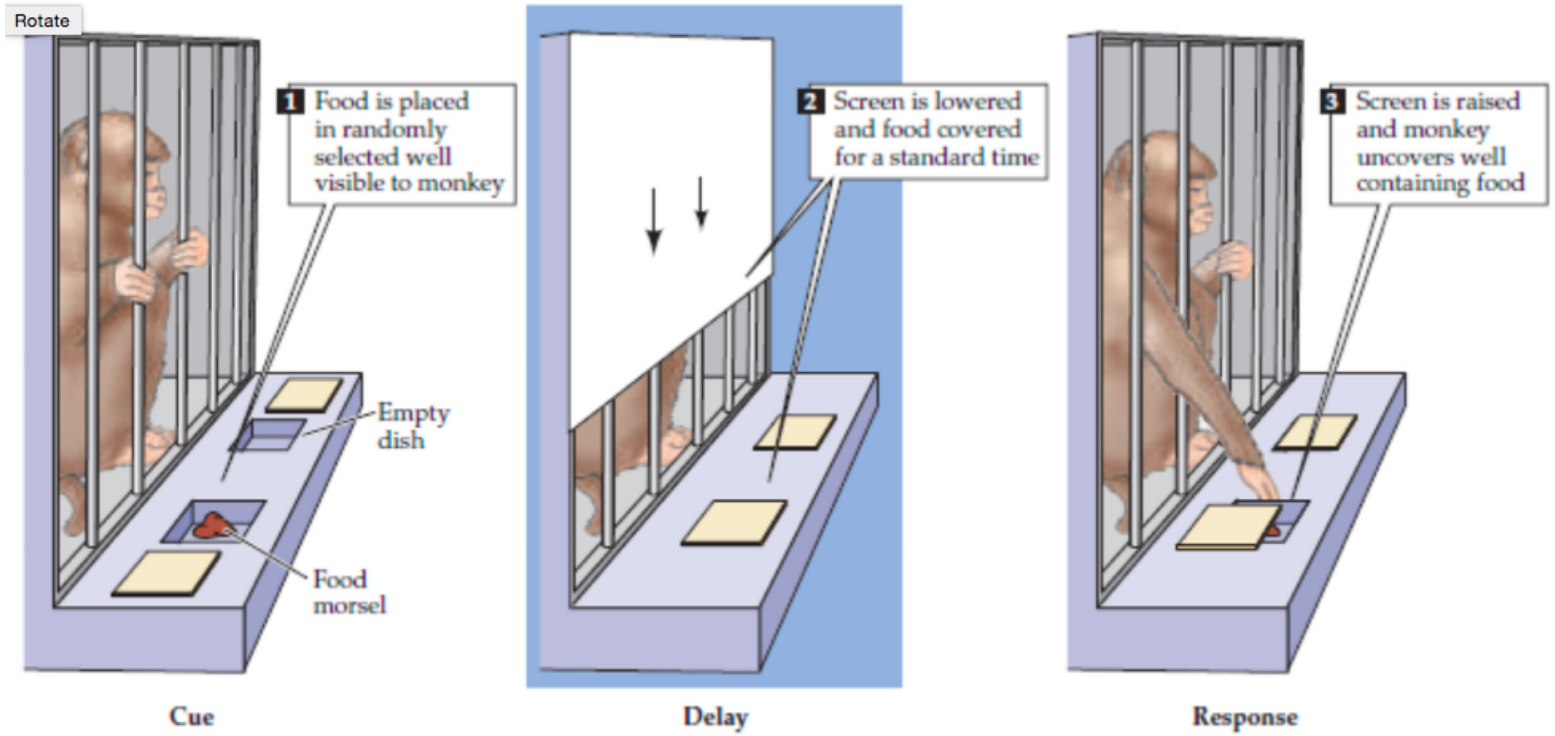
- years of studying 1000s of patients
  - generally found to:
    - decrease anxiety / arousal
    - suicidal patients more docile
    - could talk, function, etc
      - but…
        - no “drive” / loss of spontaneity
        - failure to inhibit responses
          - perseveration
          - can’t change strategies
        - epilepsy
        - decreased pain sensation
        - personality changes (Phyneas Gage)
    - no IQ drop - shows other widespread roles of PFC
    - lobotomies not a good idea



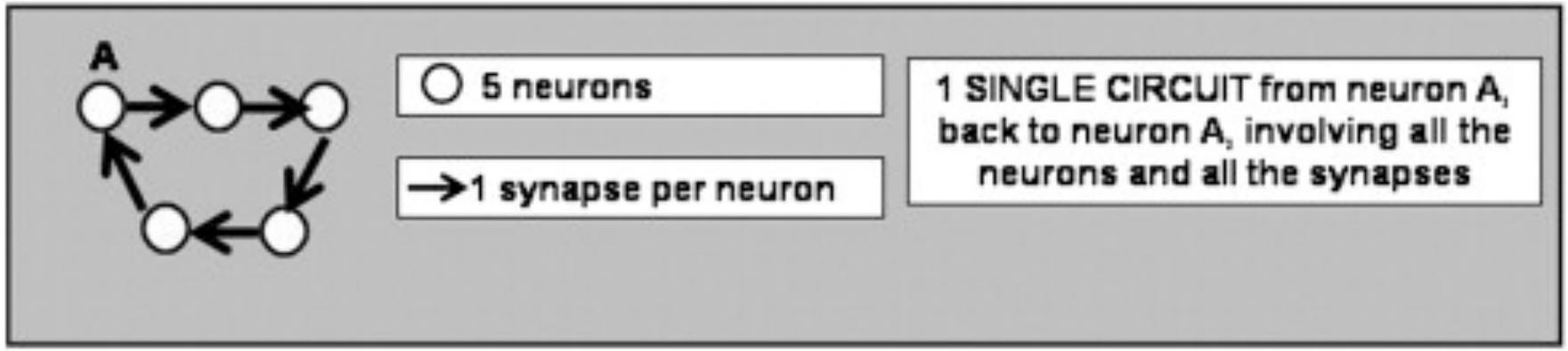
Frontal: selecting and planning appropriate behavioral responses

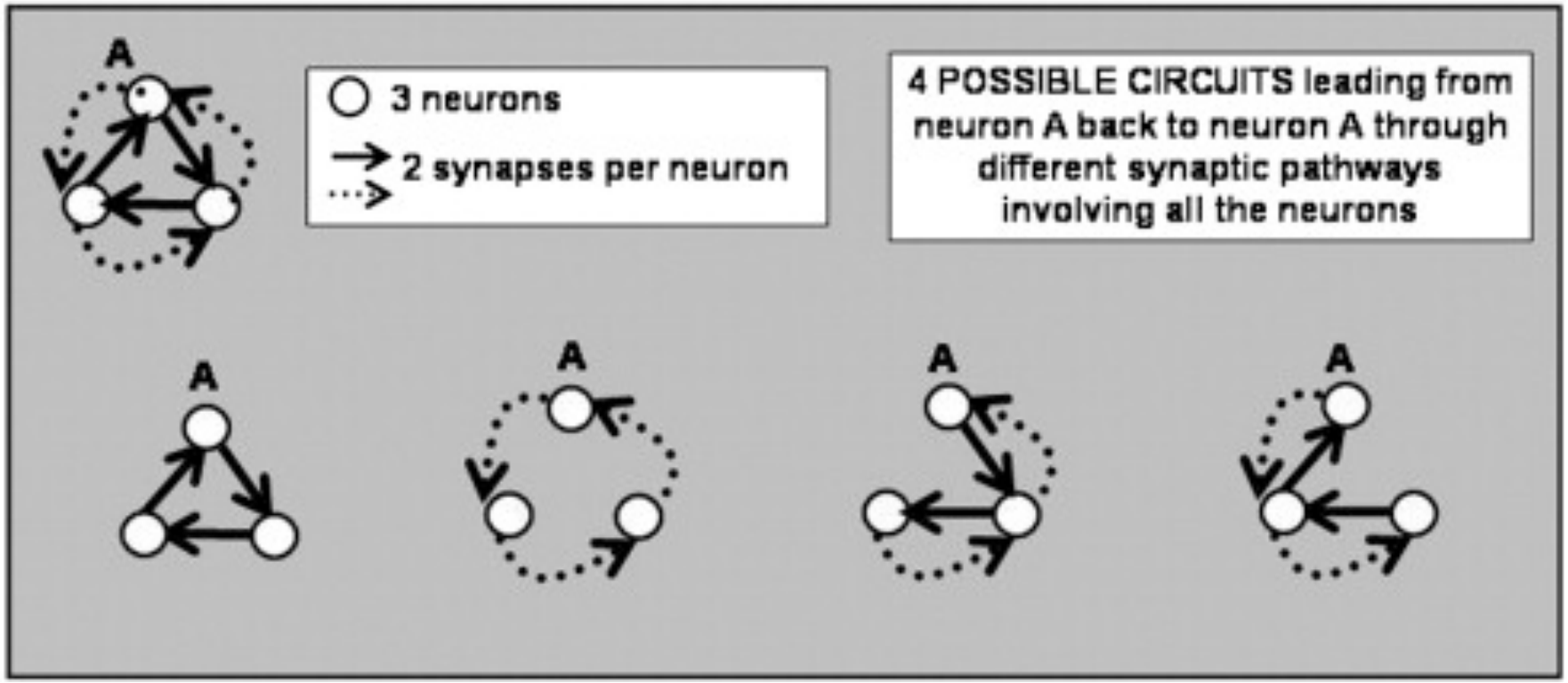
Electrophysiology of monkey brains

- Some frontal cortical neurons respond only while the monkey is performing a **delayed-response** task
  - Reverberating circuits / working memory
- Other neurons only fire at specific points of a specific sequence



Short-Term/Working Memory





Complex brain functions are simply built from multiple smaller functions happening in parallel and in sequence

Cognitive steps in very basic Stimulus-Response

1. Attend to stimuli - parietal
2. Identify stimulus - temporal
3. Select and plan appropriate reaction - frontal

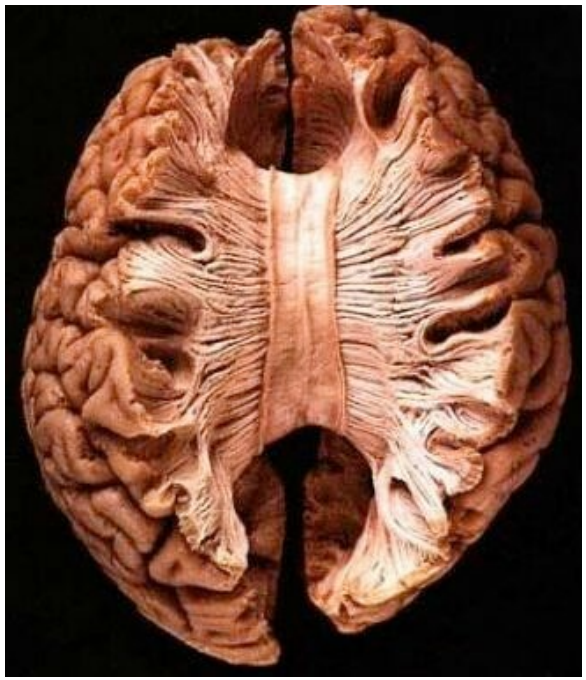
LATERALIZATION

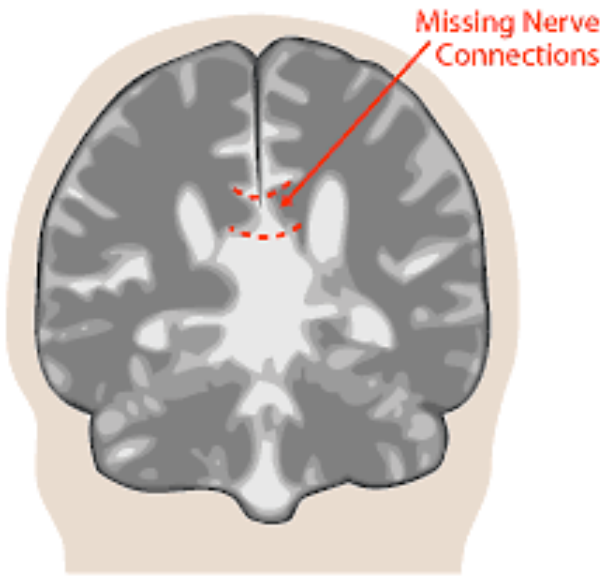
lateralization - different hemispheres control different brain functions

dominance - for most people, 1 hemisphere performs a function better than the other (e.g., language)

Left	Right
verbal	visuospatial
sequential, temporal, digital	simultaneous, spatial
logical, analytic	holistic, gestalt
rational	intuitive
positive affect	negative affect

- **Major fiber pathways connecting the hemispheres:**
  - corpus callosum - cortical and subcortical connections
    - largest interhemispheric connection (~200-300 million axons)
    - the cortical regions associated with hands and feet are about the only parts of the body not connected by the corpus callosum
      - they function almost totally under the control of 1 hemisphere
      - allows for complete independence of movement of digits



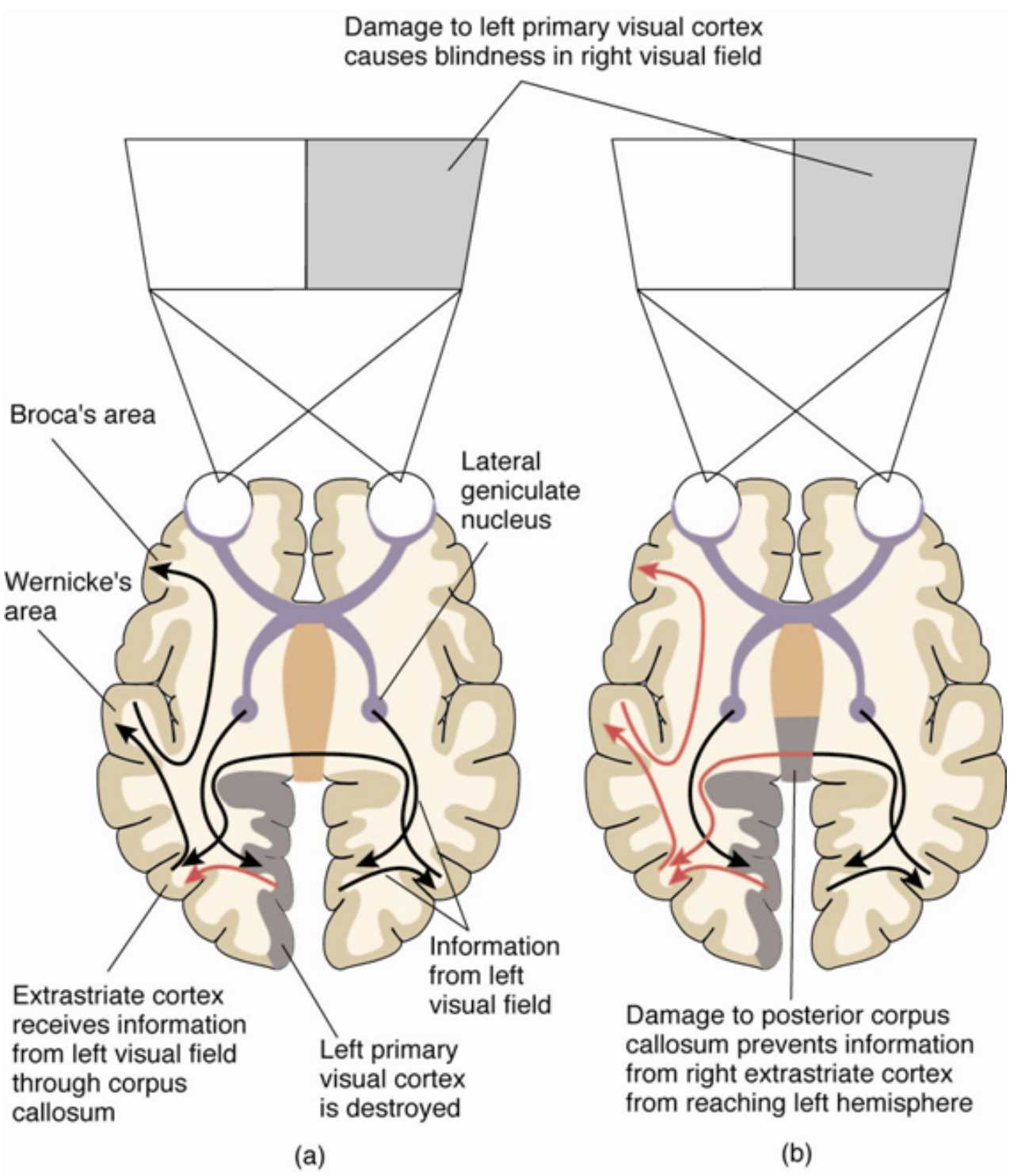


Agenesis of the
Corpus Callosum

- **Minor connections:**
  - anterior commissure - in front of hypothalamus
  - posterior commissure
  - hippocampal commissure
  - massa intermedia - connection between thalami that bridge the 3rd ventricle (~15% of the population does not have it)

- all of these connections are 2-way streets
- crossing over involves degradation of the info
  - info that crosses isn't as "good" as original
    - resolution is worse
    - time delay (50ms)

- most of this research has been done on pathological brains
  - normal patients can be studied with a tachistoscope or on dichotic listening tasks
    - however, the 2 hemispheres usually function in unison


Damage to left primary visual cortex causes blindness in right visual field
Broca's area
Lateral geniculate nucleus
Wernicke's area
Information from left visual field
Extrastriate cortex receives information from left visual field through corpus callosum
Left primary visual cortex is destroyed
(a)
Damage to posterior corpus callosum prevents information from right extrastriate cortex from reaching left hemisphere
(b)

Commissurectomy:

- splitting of the corpus callosum to reduce seizures

- if a picture is presented to the L field of vision, > processed by Right hemisphere
  - right handed subjects can't name it, but can recognize by touch w/ L hand
    - faces are complex geometric patterns, which are recognized best by the visuospatial processing of the R hemisphere

- if a picture is presented to the R field of vision > processed by Left hemisphere
  - patient can name picture
    - language is (mostly) "in the left hemisphere"

  - normal subjects don't have to worry about this - based on type of info, the hemisphere best suited for response typically responds

Split-brain person:

can name objects in right hand, not left hand

left hemi (r field) responds to verbal instructions

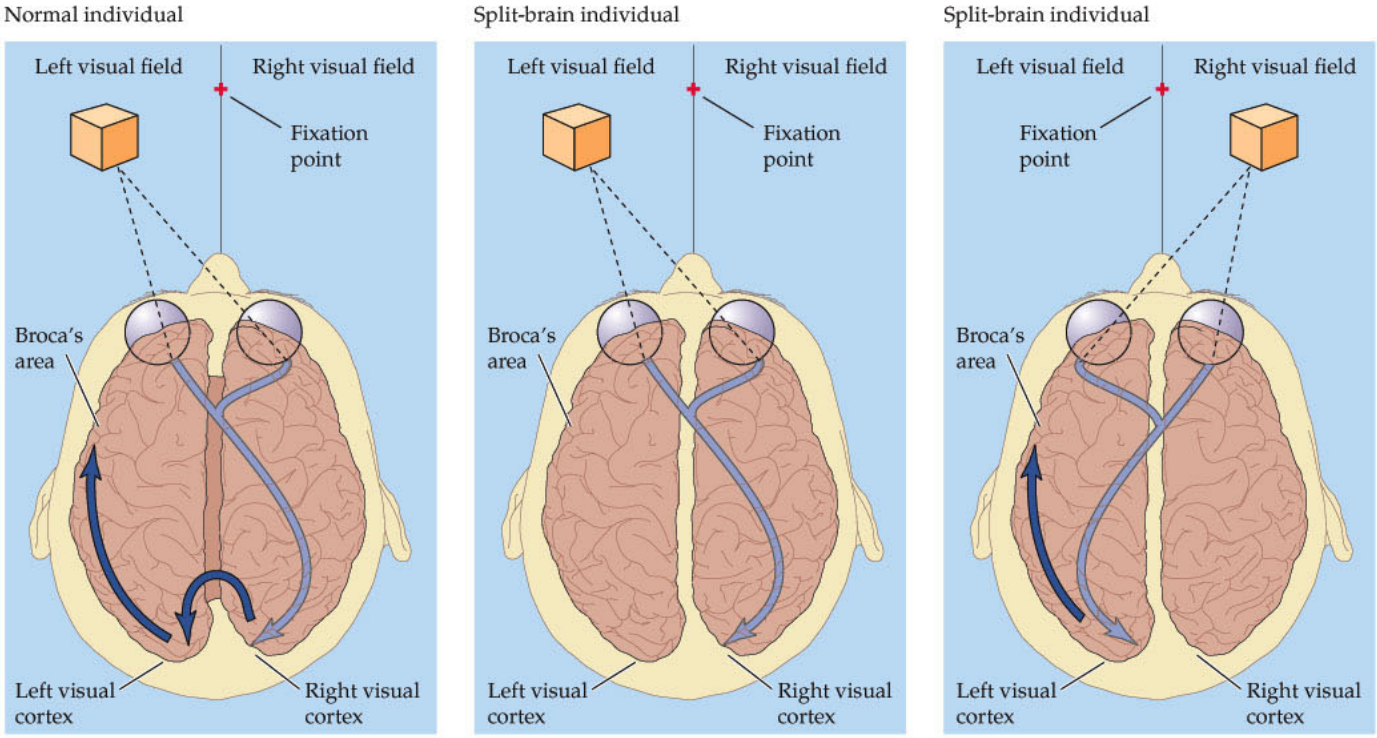
right only pictoral instructions

(A)

(C)

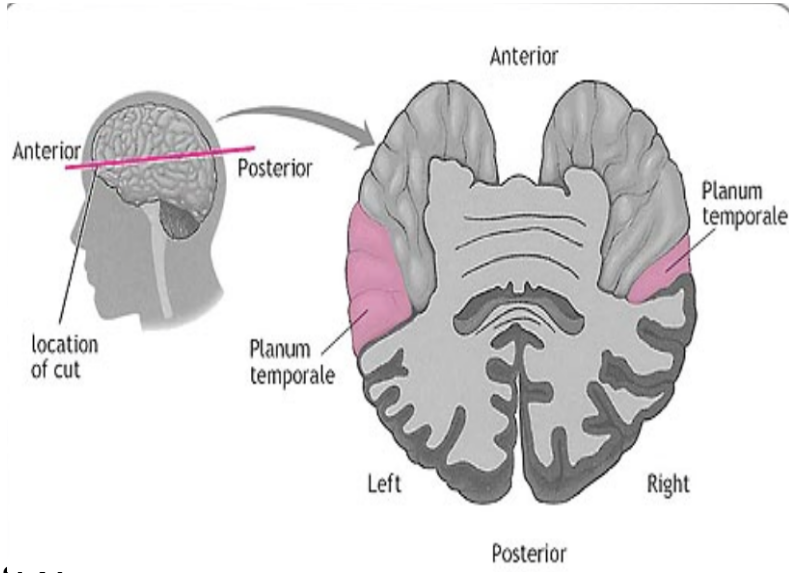
Left hemisphere functions	Right hemisphere functions
Analysis of right visual field	Analysis of left visual field
Stereognosis (right hand)	Stereognosis (left hand)
Lexical and syntactic language	Emotional coloring of language
Writing	Spatial abilities
Speech	Rudimentary speech

(B)



NEUROSCIENCE, Fourth Edition, Figure 27.3

Anatomical Asymmetries:



- the 2 hemispheres are <u>morphologically</u> different
  - <u>Left</u>
    - shorter central sulcus (flatter, not as steep)
    - larger insular cortex
    - “double” cingulate gyrus
    - more gray matter (either more cells, or larger cells?)
    - larger planum temporale (Wernicke’s Area - right is sometimes bigger in females)
    - larger posterior thalamic nucleus
    - left motor area larger - right hand usually more dexterous
    - larger and more convoluted Broca’s area
    - wider and longer occipital lobe
    - more DA, NE, 5HT, ACh, and GABA (probably because there are more cells)
  - <u>Right</u>
    - heavier
    - “double” Herschl’s gyrus (primary auditory)
    - larger Medial Geniculate Nucleus (auditory thalamus)
    - wider and longer frontal lobe

these differences are probably genetic, but may also be related to use

HANDEDNESS:

- in R handers, L corticospinal tract has more fibers
  - 85% of the population is R handed
    - 96-97% of these have L hemisphere language

  - 15% of the population is L handed or mixed
    - 70% of these have L hem language
    - 15% have R hem language
    - 15% have language in both hems

- aphasias are usually worse for R-handers (more lateralized)
- handedness switches about 10x (???) during the 1st 8 years of life

- “default” is probably R-handed
  - many cases of L-handedness most likely occurs as a result of early nervous system insult
  - more male L-handers
    - more male early nervous system injury
      - autism
      - dyslexia
      - cerebral palsy
  - ...however, there are also genetic aspects to L-handedness

Why Asymmetry?

- more efficient to localize complex functions
- Perhaps:
  - the hemispheres are lateralized for motor function rather than language
    - language then evolved from gesturing
  - also, processing of sensory info:
    - L - sequential, analytical info (this leads to language and precise motor function)
    - R - simultaneous, holistic
- early damage to L language areas can lead to R hemisphere “taking over” language
  - below 4 or 5 - earlier is better

...but, performance IQ may drop (due to “crowding”)

Gender differences in the lateralized anatomy of the brain:

- PET shows that females have greater activity in the corpus callosum, L frontal cortex & cingulate cortex

- females have 5-15% (25,000,000) more axons in the corpus callosum
  - females are generally less lateralized
  - more resistant to effects of unilateral brain damage

- Left-handed people have more fibers as well
  - so, left-handed females are the least lateralized
    - most resistant to effects of unilateral damage

- Right-handed males are the most lateralized