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
Cortical inputs / outputs:
- brainstem
- midbrain
- thalamus
- basal ganglia
- cerebellum
- limbic system structures
- basal forebrain
- other cortical areas
Inputs – each lobe’s association cortex has a distinct but overlapping set of inputs

cortico-cortical connections (white matter)

• primary <> secondary sensory cortices
• primary <> secondary motor cortices
• association areas <> other association areas
• corresponding areas in other hemisphere via inter-hemispheric connections
  • corpus callosum / anterior commissure
Association Cortices

- Motor Cortex
- Somatosensory Cortex
- Association Cortex
- Parietal Lobe
- Temporal Lobe
- Occipital Lobe
- Broca's Area
- Auditory Cortex
- Wernicke's Area
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
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)
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

• dorsal medial parietal cortex – more visual
Normal

Left hemisphere lesion (minimal right neglect)

Right hemisphere lesion (severe left neglect)

Partial bilateral lesion (severe right neglect)

(A) Attending to the left visual field

(B) Attending to the right visual field
contralateral neglect syndrome
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 from parietal (and frontal) association areas to primary sensory cortices
Primary processing is “enhanced” for attended stimuli
Temporal: identifying stimuli
Temporal: identifying stimuli

in 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
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
Wisconsin card sorting

Sort by color:

Sort by shape:

Sort by number:
• 1935 Portuguese neurologist (Moniz) heard that focal lesions of PFC mellowed out aggressive chimps... within months, human prefrontal lobotomies
• years of studying 1000s of patients - generally found to:
  • decrease anxiety / arousal
  • but...
    • failure to inhibit responses
      • perseveration
      • can’t change strategies
    • loss of spontaneity
    • 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

1. **1 Single Circuit** from neuron A, back to neuron A, involving all the neurons and all the synapses.

2. **4 Possible Circuits** leading from neuron A back to neuron A through different synaptic pathways involving all the neurons.
LATERALIZATION

lateralization - different hemispheres control different brain functions

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

<table>
<thead>
<tr>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>verbal</td>
<td>non-verbal, visuospatial</td>
</tr>
<tr>
<td>sequential, temporal, digital</td>
<td>simultaneous, spatial</td>
</tr>
<tr>
<td>logical, analytic</td>
<td>holistic, gestalt</td>
</tr>
<tr>
<td>rational</td>
<td>intuitive</td>
</tr>
<tr>
<td>positive affect</td>
<td>negative affect</td>
</tr>
</tbody>
</table>
**Left Brain**
- Logical
- Sequential
- Rational
- Analytical
- Objective
- Looks at parts

**Right Brain**
- Random
- Intuitive
- Holistic
- Synthesizing
- Subjective
- Looks at wholes

(Source: Funderstanding.com, Inc., New Jersey)

**Left and Right Brain Functions**

**Left-Brain Functions**
- Analytic thought
- Logic
- Language
- Science and math

**Right-Brain Functions**
- Holistic thought
- Intuition
- Creativity
- Art and music
• 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
• **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
Commissurectomy:

- splitting of the corpus callosum to reduce seizures

- if a picture is presented to the R field of vision, patient can name picture
  - language is (mostly) “in the left hemisphere”

- if a picture is presented to the L field of vision, 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 visuo-spatial processing of the R hemisphere

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

- the 2 hemispheres are morphologically different
  - **Left**
    - 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)
  - **Right**
    - 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
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
  - areas correlated with being more “emotional”
- females have 5-15% (25,000,000) more axons in the corpus callosum
  - females are 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