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Cerebral Cortex

M1 – CNS Sequence
Peter Hitchcock, Ph.D.

Winter, 2009
The topic of today’s lecture is the cerebral hemispheres—the cerebral cortex and the underlying subcortical white matter.

I. subdivisions of cerebral cortex  
II. cellular anatomy of neocortex  
III. anatomical subdivisions of neocortex  
IV. functional subdivisions of neocortex  
V. specializations of each hemisphere; hemispheric dominance  
VI. subcortical white matter  
VII. genetic defects in cortical development  
VIII. imaging electrical activity in the cerebral cortex  
IX. blood supply to the cerebral hemispheres  
X. a word about consciousness
The cerebral cortex is the site of the highest order integration of sensory, motor and consciousness activities.
• The cerebral cortex in 80% of the mass of the brain.
• The surface area is roughly equivalent to a page of newspaper (2.5ft$^2$).
• The gray matter consists of cell bodies of neurons that are arranged in layers.
• Underlying the gray matter is a large area of white matter.
• There are three basic types of cortex:
  – Neocortex (new)
  – Mesocortex (middle)
  – Allocortex (other)
• cortical areas.
Neocortex (90%)

Meso- and Allo-cortex (10%)

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Tabulated data on the different types of cortex:

neocortex (new cortex) - 6 layers
  a. ideotypic cortex - 1° motor and sensory cortex
  b. homotypic cortex - association areas
     1. unimodal association cortex -
     2. multimodal association cortex -

mesocortex (middle cortex) - 3-6 layers - related to limbic system -
  a. cingulate gyrus
  b. parahippocampal gyrus

allocortex (other cortex) - 3 layers
  a. archicortex - hippocampal formation
  b. paleocortex – piriform cortex
Neocortex constitutes approximately 90% of all cortex and contains 6 identifiable cellular layers. The major neuronal types in neocortex are the pyramidal cells and granule cells.

Layer 4 is the recipient zone of thalamocortical axons. Layers 3, 5 and 6 are the output layers, sending axons to other cortical or subcortical targets. Layer 5 is the principal output layer to subcortical targets.
• The cerebral cortex is responsible for the perception and conscious understanding of all sensations and the integration of different sensory modalities. It is involved in higher cognitive and advanced intellectual functions. It is responsible for features such as emotion, personality and intellect.

• The cerebral cortex is also involved in planning and executing complex, voluntary motor activities.

• One can divide the cerebral cortex into an anterior ‘expressive’ region and a posterior ‘receptive’ region.
The cerebral hemispheres are divided into lobes: cortex and underlying white matter.
Island lobe
The limbic lobe lies on the medial wall of the cerebral hemisphere.
Further anatomical subdivisions of the lateral surface of the cerebral hemisphere
Further anatomical subdivisions of the medial surface of the cerebral hemisphere.
Different areas of neocortex vary as to overall thickness, thickness of the individual layers, differences in cell size and differences in cell density.
In a paper published in 1909, Brodmann identified more than 40 cortical areas based on cellular and laminar histology of cerebral cortex.

This is the most widely reproduced figure in the fields of neurology and neuroanatomy. Brodmann’s nomenclature is still used today, e.g., area 17 is primary visual cortex.
Cerebral cortex can be broadly divided into an anterior, expressive region (anterior to central sulcus) and a posterior receptive region (posterior to central sulcus).

Cortex is also divided into discrete regions subserving sensory and motor functions.

Primary cortical areas occupy specific sites:

- Olfactory cortex: preamygdaloid and parahippocampal gyrus
- Somatosensory cortex: postcentral gyrus
- Auditory cortex: transverse temporal gyrus
- Visual cortex: cortex surrounding the calcarine sulcus - area 17, primary visual cortex
- Motor cortex: precentral gyrus
The primary sensory and motor areas of the cerebral cortex are precisely topographically organized. This topographic organization reflects the organization of the ascending sensory pathways and nuclei within the dorsal thalamus as well as the descending motor pathways.

These topographic “maps” are distorted, reflecting sensory specializations of the periphery, such as the fine somatosensory discrimination of the hands and peri-oral regions.

The organization of primary cortical areas are species-specific and reflect the specialized use of the sensory and motor periphery.
In rodents, individual whiskers on the face are represented in primary somatosensory cortex by complex ‘barrels’ of cells.
In primary sensory areas, each cortical neuron has a receptive field that corresponds to a location on the sensory sheet (body surface in this instance).

Sensory ‘maps’ extend throughout the depth of the cortex and are functionally organized based on the specificity of the receptors.
Association cortical areas surround the primary cortical areas, and can be divided into unimodal and multimodal regions. Unimodal association cortex relates to a single primary region only, whereas multimodal cortex integrates information relating to multiple primary and unimodal regions.
Stimulating illusory own-body perceptions

behavioral responses

- movement
- somatic sensation
- auditory sensation
- out-of-body experience

★ epileptic focus

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The relative amounts of association cortex can be ordered phylogenetically.
Hemispheric dominance: Higher-order perceptual and motor functions are performed predominantly in one hemisphere or the other:

Right brain: left visual field, drawing, music, spatial perception

Left brain: right visual field, language, calculation
In this chimeric image, the left hemisphere, which is dominant for speech ‘sees’ the man, whereas the right hemisphere, which generally has no capacity for speech ‘sees’ the woman.

In patients in which the hemispheres are disconnected by sectioning the corpus callosum and anterior commissure, one can selectively query one hemisphere or the other.

When asked, a split-brain patient will report seeing a man.

If asked to use the left hand and point to separate photographs, in a split-brain patient the left hand will select the woman’s face.
A: normal control

B: split brain patient
Much of the cerebral hemispheres is occupied by subcortical white matter, which is anatomically organized.

There are three types of fibers in the subcortical white matter:
1) projection fibers - leave the hemisphere for subcortical targets
2) commissural fibers - interconnect the two hemispheres, L-R and R-L
3) association fibers (2 types) - interhemispheric connections, L-L and R-R
This dissected brain illustrates projection fibers, that innervate subcortical targets, e.g., thalamus, brainstem and spinal cord.
corona radiata
internal capsule
The corpus callosum is the largest of the two structures that contain commissural fibers. Commissural fibers interconnect both homologous and heterologous areas of the two hemispheres.
CORPUS CALLOSUM

Body

Splenium

ANTERIOR COMMISURE

Genu

Rostrum

Commissural Fibers
The anterior commisure is the second major structure that contains commissural fibers.
Association fibers do not leave the cerebral hemisphere, and can be classified as either long or short.
Lateral surface of the left hemisphere

- Central sulcus
- Postcentral gyrus
- Precentral gyrus
- Arcuate fasciculus
- Angular gyrus
- Broca's area
- Lateral sulcus
- Superior temporal gyrus
- Wernicke's area
arcuate fasciculus
Cerebral arteries supply the cortex and superficial white matter

- middle cerebral artery
- anterior cerebral artery
- posterior cerebral artery

border zones

Cerebrovascular disease is a common form of cortical injury and disability.
Imaging electrical activity in the brain with fMRI

Regional cerebral blood flow - 0.5% difference in blood flow

Language mapping in normal volunteers
Development of the central nervous system - 25 days to 9 months.

Note the enormous growth of the cerebral hemispheres relative to other brain regions.
Genetic disorders can dramatically affect cortical development.

a. normal
b. schizencephaly
c. lissencephaly
d. double cortex
e. heterotopia
Consciousness: def - ‘an awareness of one’s surroundings, of the self and of one’s thoughts and feelings.’

What are the mechanisms that modulate consciousness and unconsciousness?

Normal states of consciousness and unconsciousness, i.e., wakefulness and sleep, are due to normal alterations in the modulation of cortical activity controlled by circuits that originate in brainstem and nuclei in the base of the forebrain.

Abnormal states of consciousness, i.e., hallucination, concussion, coma, persistent vegetative state, are due to disruption (temporary or permanent) to either the neuromodulatory systems that control cortical activity or direct injury to the cerebral hemispheres themselves.
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