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Normal CNS, Special Senses, Head and Neck
TOPIC: CEREBRAL HEMISPHERES

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LECTURE: Wednesday, 16 March 2009, 1:00p.m. – 2:00p.m.

READING: No assigned readings

OBJECTIVES AND GOALS:

From the reading and lecture the students should know:

- 1) the cellular anatomy of neocortex
- 2) the organization of a cortical column and its importance
- 3) locations of primary sensory cortices (auditory, visual, somatic sensory, olfactory, gustatory).
- 4) the laterality of sensory representations
- 5) the concept and importance of topographic organization
- 7) spatial and functional relations of association and primary cortices
- 8) how projection fibers, association fibers and commissural fibers relate to the cerebral cortex, corona radiata, corpus callosum and internal capsule
- 9) the location and function of the arcuate and superior longitudinal fasciculi.
- 10) Cerebral dominance of cortical functions

SAMPLE EXAM QUESTION:

Which of the following features is NOT characteristic of a typical primary sensory area in neocortex.

- A. Receives input from the dorsal thalamus
- B. Projects axons back to the dorsal thalamus
- C. Is topographically organized
- D. Contains 3 cellular layers

Answer. D

I. Introduction:

This lecture will deal with the **cerebral cortex** and the **sub-cortical white matter**. The cerebral cortex is the site of the highest order sensory, motor and consciousness activities. Neocortex functions to: 1) integrate sensory information and generate sensory perceptions, 2) direct attention, 3) control eye movements (part of directing attention), 4) program and execute motor behaviors, 5) control behavior and motivation, 6) control both motor and perceptual aspects of language, and 7) encode memories.

II. Subdivisions of cerebral cortex

a. The **cerebral cortex** makes up 80% of the mass of the brain, and consists of an outer layer or sheet of neuronal cell bodies that is only a few millimeters thick and arranged into layers parallel to the surface of the brain. Cortex can be divided into 3 types based upon location, function and the number of cellular layers.

1. 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 -
2. mesocortex (middle cortex) - 3-6 layers (transitional) - related to limbic system: cingulate gyrus, parahippocampal gyrus, uncus
3. allocortex (other cortex) - 3 layers
 - a. archicortex – hippocampal formation
 - b. paleocortex – piriform cortex

II. Cellular anatomy of neocortex.

- Neocortex consists of six layers based upon the size and spatial density of the neurons. The numbering is from layer I, the most superficial layer (nearest the pia) to layer VI, the deepest layer (lying just above the subcortical white matter).
- There are two principle neuronal types in cortex: **granule cells** (sometimes called stellate cells) and **pyramidal cells**. These names are descriptive and relate to the size and shape of the neuronal cell bodies. Granule cells are local-circuit neurons (**interneurons**) within the cortex, whereas pyramidal cells are projection neurons, which send their axons to other cortical and subcortical areas.
- Afferent, thalamocortical axons terminate in layer IV. Layers III and V contain neurons (**pyramidal cells**) whose axons project out of cortex to other cortical and/or subcortical targets.

III. Anatomical subdivisions of cerebral cortex – lobes, sulci and gyri

- A. The cerebral cortex is subdivided into six lobes:
- 1) frontal lobe
 - 2) parietal lobe
 - 3) occipital lobe

- 4) island lobe
- 5) temporal lobe
- 6) limbic lobe (a functional subdivision)

B. Each lobe can be subdivided by the pattern of sulci and gyri. For example:

- 1) frontal lobe
 - superior, middle and inferior frontal gyri
 - central sulcus
 - pre-central gyrus
- 2) parietal lobe
 - central sulcus
 - post-central gyrus
 - superior and inferior parietal lobules
- 3) occipital lobe
 - calcarine sulcus
 - cuneate and lingual gyri
- 4) temporal lobe
 - superior, middle and inferior temporal gyri
- 5) limbic lobe
 - cingulate sulcus
 - cingulate gyrus

C. Carl Brodmann's nomenclature based on cortical histology

IV. Functional subdivisions of cortex:

A. neocortex is functionally subdivided into numerous specific **primary** and **association areas** that subserve specific functions.

1. **Primary sensory** areas receive thalamocortical projections associated with sensory pathways from spinal cord, brainstem, the retinas and the olfactory epithelium. **Primary motor** cortex is the origin of the corticobulbar and corticospinal axons. Primary areas occupy specific lobes and gyri.

- a. olfactory cortex – medial temporal lobe; prepyriform and periamygdaloid cortex
- b. somatosensory cortex – parietal lobe; postcentral gyrus
- c. auditory cortex – temporal lobe; transverse temporal gyrus
- d. visual cortex – occipital lobe; lingual and cuneate gyri
- e. motor cortex – frontal lobe; precentral gyrus

●A general property of these primary areas (with the exception of olfactory cortex) is that they are **topographically organized**. The peripheral “sensory sheet” is represented in a coherent point-to-point fashion in the primary sensory cortex.

Similarly, primary motor cortex is topographically organized according to the peripheral muscle groups. There are **sensory “maps”** in the primary sensory cortical areas. (Although not as precisely organized, there are topographic maps in **association cortex** [see below] as well.) There is a **motor map** within primary motor cortex. The different “maps” will be described in class.

Within a sensory map, each neuron has a **receptive field** that corresponds to a location on the sensory surface, e.g. skin. These will be described in class.

Primary sensory and motor cortex are functionally organized into columns. For example, in primary somatosensory cortex, each point on the body surface is represented in the post-central gyrus by a column of cells passing through all 6 cortical layers.

2. **Association cortical areas** surround the primary cortical areas and are heavily interconnected with them. In humans, association cortex constitutes the bulk of the cortical area. Association cortex is hierarchically organized into **unimodal** association cortex, which is modality specific and directly connected to the nearby primary sensory or motor area, and **multimodal** association cortex, which receives input from the unimodal areas. Association cortex serves as the neural interface between sensory and motor areas in cortex, and it is the site of higher cognitive, emotional and perceptual functions.

Example: induced out-of body experience

V. Specializations of each hemisphere – hemispheric dominance.

Numerous functions are performed predominantly in one or the other hemisphere. For example, in most people, the left cerebral hemisphere is specialized for language.

Examples: handedness – left vs. right
visual and motor tasks in “split brain” individual
coordination of motor tasks between hands

VI. The Sub-cortical white matter.

White matter occupies a large proportion of the cerebral hemispheres, and is composed of myelinated fibers that interconnect multiple areas of the cerebral hemispheres as well projecting to sub-cortical structures.

A. There are three types of fibers, based upon the areas they connect:

1. **Projection fibers** are axons that originate from pyramidal cells in layer 5 and 6 that project to sub-cortical structures (thalamus, brainstem, spinal cord). These axons pass through the internal capsule. Between the cortex and internal capsule, these fibers are known collectively as the **corona radiata**.
2. **Commissural fibers** are axons that originate from pyramidal cells in layer 3 that interconnect the two hemispheres. There are two

commissures that connect the cerebral hemispheres: the **corpus callosum** and the **anterior commissure**. Commissural fibers interconnect both homologous (similar) and heterologous (dissimilar) areas of the two hemispheres. The corpus callosum is the largest (by far) of the two commissures, and is divided into three zones, from anterior to posterior: **genu**, **body** and **splenium**.

3. **Association fibers** are axons that originate in layer 3 that interconnect different areas within a hemisphere, e.g. primary and association visual areas. **Short** association fibers connect adjacent gyri, whereas **long** association fibers interconnect different cortical regions in two lobes. Two examples of long-association-fiber pathways are: the **arcuate fasciculus**, which interconnects Broca's area (frontal lobe) and Wernicke's area (parietal lobe) and is important for the motor and perceptual aspects of speech, and the **superior longitudinal fasciculus**, which interconnects occipital and frontal lobes. The association fibers are responsible for the parallel, reciprocal and hierarchical organization of the cerebral cortex.

VII. Blood supply to the cerebral cortex

The cerebral hemispheres are supplied by the anterior, middle and posterior cerebral arteries. Cerebrovascular disease is a common form of cortical injury.

VIII. Imaging electrical activity in the cerebral cortex.

1. Local electrical activity in the cerebral cortex is coupled to an increase in local blood flow. This is known as **regional cerebral blood flow** and is used in some imaging techniques.
2. With advances in MRI, it is now possible to image activity of the cerebral cortex during complex motor and cognitive tasks.

IX. Genetic defects in cortical development

1. Genetic disorders can result in malformations of cortex during late stages of brain development. These disorders reflect alterations in cell proliferation and/or migration.
2. The most common result of severe cortical malformations is profound mental impairment, epilepsy or paralysis.

X. A word about consciousness....