Medical Neuroscience | Tutorial Notes

Overview of Cortex and Cortical Circuits

MAP TO NEUROSCIENCE CORE CONCEPTS[1]

NCC1. The brain is the body's most complex organ.

NCC3. Genetically determined circuits are the foundation of the nervous system.

NCC7. The human brain endows us with a natural curiosity to understand how the world works.

NCC8. Fundamental discoveries promote healthy living and treatment of disease.

LEARNING OBJECTIVES

After study of today's learning, the student will:

1. Discuss the embryological origin of the cerebral cortex.
2. Discuss differences in the cytoarchitecture across the cerebral cortex.
3. Discuss the anatomical organization of the cortical microcircuit.
4. Characterize the "ACC" functions of the cortical microcircuit.

TUTORIAL OUTLINE

I. Embryological origin of the cerebral cortex

A. generation and differentiation of neurons and glia

1. nearly all neurons are generated by the middle of the second trimester; thereafter, *only very few neurons are ever generated in the CNS!*
2. neuronal and glial genesis occurs in the ventricular zone of the developing forebrain: the **telencephalon**, which is derived from the **prosencephalon** (see **Figure 22.3**[2])
   a. cell division occurs against the wall of the ventricles where precursor cells divide and produce other stem cells for many mitotic cycles (see **Figure 22.7**)
   b. some are destined to differentiate into a glial precursors and others into neuronal precursors, called neuroblasts
3. after many cycles of mitotic activity, some postmitotic neuroblasts migrate away from the ventricular zone toward the developing cerebral cortex, called the **cortical plate**
   a. many neurons in the CNS are guided to final destinations by glial cells that span the distance between the ventricular zone and the pia mater

[1] Visit **BrainFacts.org** for *Neuroscience Core Concepts* (©2012 Society for Neuroscience) that offer fundamental principles about the brain and nervous system, the most complex living structure known in the universe.
[2] Figure references to Purves et al., *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc., 2012. [click here]

b. for the developing cortical plate, neuroblasts migrate along radial glial cells (see **Figure 22.12**)

4. consequently, the cortical plate matures into the cerebral cortex in each hemisphere, which remains a continuous "sheet" of neural tissue that becomes increasingly folded into the outer surface of the forebrain

II. Anatomical organization of the cortical microcircuit

A. the continuous "sheet" of neural tissue in each hemisphere is actually *multi-layered*, with different layers of neurons and intrinsic connections serving somewhat different purposes

B. the "canonical" cortical microcircuit

1. thalamus projects to (granular) layer 4

a. called "granular" because of the numerous small stellate neurons that are found in abundance in this layer (see **Figure 26.2A**)

b. at low magnification, this layer looks like grains of sand (hence the term "granular")

2. layer 4 projects to upper (supragranular) layers (2 and 3)

3. upper (supragranular) layers project to lower (infragranular) layers (5 and 6), and to other cortical areas, including corresponding areas in the opposite hemisphere

4. layer 6 projects up to layer 4, and back down to the thalamus

5. layer 5 projects to the basal ganglia (caudate nucleus and putamen), brainstem and, for some areas, the spinal cord

C. in addition, there are local connections within each cortical layer

1. each neuron tends to project diffusely to its near neighbors

2. each neuron tends also to project to neurons in surrounding columns that have similar functional properties ("*like connects to like*")

III. The "**ACC**" of the cortical microcircuit

A. all this circuitry serves to *amplify*, *compute* and *communicate*

1. *amplify* thalamic input

2. *compute* additional functional properties that may not be present at antecedent neural processing centers (e.g., the thalamus)

3. *communicate* information to other cortical areas and to subcortical centers (e.g., thalamus, basal ganglia, brainstem)

B. different divisions (areas) of the cerebral cortex have slight modifications of these basic layers, which provides for the recognition of anatomical and functional distinctions across the cortex

IV. Cytoarchitecture of the cerebral cortex

A. "cytoarchitecture" refers to the cellular composition of neural tissue

1. recall that neural tissue comprise numerous different types of cells (neurons and glia) that vary considerably in size and morphology
2. different locations in the cerebral cortex differ in subtle (and sometimes not so subtle) cytoarchitectonic features

B. around the turn of the 20th century, several important histologists began to stain brain tissue to reveal the cellular anatomy of neural tissue

1. one important figure in the history of cortical exploration was a German neuroanatomist, **Korbinian Brodmann** (1868-1918)[3]
2. Brodmann studied cortical tissue with a stain that reveals the presence of cell bodies, called a Nissl[4] stain
3. Brodmann famously mapped the cytoarchitecture of the cerebral cortex proposing some 50 or so divisions based on the cytoarchitecture (e.g., cell density, cell size, layer thickness, radial organization of cells, etc.) (see **Figure 26.2B; Box 26A**)

C. differences in the cytoarchitecture of different cortical areas (and differences in the input and output connections) are the basis for putative differences in the function of cortical areas; a bold hypothesis proposed by Brodmann and still under investigation for most of the human cerebral cortex

STUDY QUESTION

The "ACC" of the cerebral cortex is suggested as a useful way of remembering the principal functions of the cortical microcircuitry. So do you remember? What is the "ACC" of the canonical cortical microcircuit?

A. articulate, compound and communicate
B. amplify, coordinate and calculate
C. advance, compute and contemplate
D. amplify, compute and communicate
E. atlantic coast conference

[3] For more on the life and times of Korbinian Brodmann, visit his Wikipedia page by clicking here; and enjoy a unique artistic tribute to his seminal work at website honoring important European neuroscientists, which you can find here.
[4] In neural tissue, Nissl substance is rough endoplasmic reticulum; Nissl substance is found in cell bodies and in the proximal dendrites of the largest neurons in neural tissue.