Slicer 3 Tutorial
The SPL-PNL Brain Atlas

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Acknowledgments

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Disclaimer

It is the responsibility of the user of 3DSlicer to comply with both the terms of the license and with the applicable laws, regulations and rules.
Material

• Slicer 3

Atlas data set
  • MRI
  • Labels
  • 3D-models
Learning Objectives

- Loading the atlas data
- Creating and displaying customized 3D-views of neuroanatomy
Prerequisites

• **Slicer Training**
  Slicer 3 Training 1: Loading and Viewing Data

Overview

• Part 1: Loading the Brain Atlas Data
• Part 2: Creating and Displaying Customized 3D views of neuroanatomy
Loading the Brain Atlas Data

Slicer can load:

- Anatomic grayscale data (CT, MRI) ……
- Label maps……………………………
- 3D-Models……………………………
- MRML Scenes ………………………..
Loading the Atlas Data

Select “File” -> “Load Scene”

In the pop-up window, select the file named `brain_atlas_03_2008.mrml`, then click “Open”
Loading the Atlas Data

3D-models

MRI with overlaid label maps
Overview

• Part 1: Loading the Brain Atlas Data
• Part 2: Creating and displaying customized 3D views of neuroanatomy
Creating customized 3D-Views

By taking advantage of the ability to selectively display 3D-models, customized 3D-views of neuroanatomy can be created.
Customized 3D-Views
Creating customized 3D-Views (1)

Select the “Models” module

Select the “Display” tab

From the pull-down menu, select the models of interest, then click the checkbox, in order to make them visible in the 3D-view; to remove models from the 3D-view, uncheck the box
Creating customized 3D-Views (2)

Select the “Data” module

Click “Create Scene Snapshot”; when prompted, select a name for your customized 3D-view (e.g. Limbic System)
Creating customized 3D-Views (3)

To switch between different customized 3D-views select the view you wish to display from the pull-down menu, then click “Restore”
Teaching Files

The following slides are intended as a companion to the customized neuroanatomy views provided with the SPL-PNL Brain Atlas ("neuroanatomy teaching files"). They are meant to facilitate the user interaction with the visual material, and not as comprehensive, text-book-like descriptions of neuroanatomy. A list of recommended neuroanatomy and neuroscience reference works is provided at the end of this presentation.
The Motor System

• The motor system is organized hierarchically: the spinal cord, brainstem and forebrain contain successively more complex motor circuits

• The primary motor cortex controls voluntary movement; it projects to the brainstem and spinal cord motor neurons (*lower motor neurons*) via the corticobulbar and corticospinal tract respectively

• The activity of the motor cortex and brainstem is influenced by the basal ganglia and cerebellum
The Primary Motor Cortex

• Located in the **precentral gyrus** of the frontal lobe
• Posterior limit: *central sulcus*, which separates the precentral gyrus from the postcentral gyrus (primary somatosensory cortex)
• Anterior limit: *precentral sulcus*
• Inferior limit: *lateral sulcus* (*Sylvius*)
• Contiguous with the *paracentral lobule* on the medial aspect of the cerebral hemisphere
The Primary Motor Cortex

- Paracentral lobule
- Precentral gyrus
- Central sulcus
The Primary Motor Cortex

- There is a precise somatotopic representation of the different body parts in the primary motor cortex, with the foot and leg areas located close to the midline, and the head and face areas located laterally on the convexity of the cerebral hemisphere (motor homunculus).

- The size of the cortical representation for a specific body part is proportional to the complexity of the movements performed by that particular body part (e.g. the surface of the hand area is significantly larger than that of the foot area).
The Primary Motor Cortex

Leg area  
Face area  
Hand area
The Corticospinal Tract

- Corticospinal tract
- Precentral gyrus (primary motor cortex)
- Internal capsule
The Corticospinal Tract

- The corticospinal tract (CST) is a massive collection of axons originating in the giant pyramidal cells (Betz), in the layer V of the primary motor cortex
- The axons of the CST converge in the *posterior limb of the internal capsule*
- At the level of the midbrain, the CST occupies the ventral aspect of the cerebral peduncle; the fibers continue their descent through the ventral pons and ventral medulla oblongata
- The axons that synapse with motor neurons in the (mostly) contralateral cranial nerve nuclei (III, IV, VII, IX, X, XI, XII) form the *corticobulbar tract*
- At the level of the lower medulla oblongata, most (ca. 80%) of the corticospinal axons cross over to the contralateral side (*pyramidal decussation*), and then continue their descent through the brainstem and spinal cord as the *lateral corticospinal tract*
- The CST axons that do not cross at the medulla level continue their travel down the spinal cord as the *ventral corticospinal tract*; most of these fibers cross over to the contralateral side shortly before reaching their target, the lower motor neurons, located in the anterior horn of the spinal cord
The Basal Ganglia

- Caudate nucleus (head)
- Putamen
- Globus pallidus
- Thalamus
The Basal Ganglia

- left basal ganglia - dorsal view -

Body of caudate nucleus

Head of caudate nucleus

Tail of caudate nucleus

Putamen

Internal capsule
The Basal Ganglia

- left basal ganglia - ventral view -

Head of caudate nucleus

Body of caudate nucleus

Putamen

Globus pallidus

Tail of caudate nucleus

Head of caudate nucleus

Body of caudate nucleus

Putamen

Globus pallidus

Tail of caudate nucleus
The Basal Ganglia

• The basal ganglia (BG) are the principal component of a family of subcortical circuits linking the thalamus with the cerebral cortex
• BG play a major role in the initiation of voluntary movement, and they also participate in cognitive functions, mood and non-motor behavior
The Basal Ganglia

• The main subdivisions of the basal ganglia are:
  1. *Striatum*
  2. *Putamen*
  3. *Globus pallidus* (with two functionally distinct parts: *external* and *internal pallidal segment*)
  4. *Substantia nigra*
  5. *Subthalamic nucleus*
The Basal Ganglia

- The Striatum is composed of:
  1. *Caudate nucleus*
  2. *Putamen*
  3. *Ventral striatum* (including *Nucleus accumbens*)

- The Striatum is the *major input nucleus* to the basal ganglia
The Basal Ganglia

• The C-shaped **Caudate nucleus** is located medially and forms part of the wall of the lateral ventricle

• The head of the caudate nucleus is located above the anterior **Substantia perforata** and it is separated from the **Putamen** by the anterior limb of the internal capsule

• The **Putamen** lies laterally to the **Caudate nucleus** and medially to the **Insula**
The Basal Ganglia

- The **Pallidum (Globus pallidus)** consists of two functionally distinct subdivisions: the **external (GP_e)** and **internal (GP_i) pallidal segment**

- The **internal pallidal segment** (GP_i) represents one of the **major output nuclei** of the basal ganglia
The Basal Ganglia

- The *Subthalamic nucleus* (STN) is located between the thalamus (cranially) and the anterior part of the Substantia nigra (caudally).
- The *STN* is the only component of the basal ganglia sending *excitatory output*.
The Basal Ganglia

- The **Substantia nigra (SN)** is located in the rostral midbrain
- **SN** has two histologically and functionally distinct components:
  1. *Pars compacta* (dorsally) - contains *dopaminergic* neurons
  2. *Pars reticularis* (ventrally) - contains *GABA-ergic* neurons
The Basal Ganglia - Function

GPi sends inhibitory projections to the thalamus (ventral anterior nucleus). The thalamus, in turn, sends excitatory projections to the cortex. The subthalamic nucleus sends excitatory output to GPi. The direct pathway facilitates movement by directly inhibiting the GPi and thus disinhibiting the thalamus (ventral anterior nucleus). The indirect pathway inhibits movement, by inhibiting the GPe. This results in a decreased inhibition of the GPi and of the subthalamic nucleus, which, in turn results in an increased inhibition on the thalamocortical projections.
The Visual System

Components:

• Retina
• Optic nerve
• Optic tract
• Lateral geniculate nucleus
• Optic radiation
• Primary visual cortex
The Visual System

- Eyeball
- Optic nerve
- Optic chiasm
- Optic tract
The Visual System

Optic radiation
Optic tract
Optic nerve
Lateral geniculate nucleus
Optic chiasm
Eyeball
The Visual System

- The retina contains photoreceptor cells (rods and cones)
- The rods are responsible for the detection of dim light, whereas the cones mediate color vision
- The retina output originates in the ganglion cells
- The visual stimulus is transmitted from photoreceptor cells to the ganglion cells via an intricate network of interneurons
The Visual System

- The retinal image is inversed
- Via the **Optic nerves**, the retina projects to the **Lateral geniculate nucleus** of the thalamus, as well as to the **Pretectal area** of the midbrain (responsible for pupillary reflexes) and the **Superior colliculus** (responsible for saccadic eye movements)
- In the **Optic chiasm**, the optic nerve fibers originating in the nasal hemiretinae cross over to the contralateral **Optic tract**, whereas the fibers originating in the temporal hemiretinae do not cross over
The Visual System

- From the *Lateral geniculate nucleus*, the visual information is projected to the *primary visual cortex* via the *Optic radiation*.
- The neurons in the primary visual cortex are organized in columns, which in turn are connected via horizontal links.
- A column contains neurons with neighboring receptive fields.
The Visual System

- Lesions of specific segments of the visual system produce typical visual field defects - see illustration at http://www.brown.edu/Research/Memlab/py47/diagrams/visual-field-defects.jpg
The Limbic System

- Corpus callosum
- Cingulate gyrus
- Fornix
- Lateral ventricle (occipital horn)
- Hypothalamus
- Amygdaloid complex
- Hippocampus
The Limbic System

The limbic system (aka the limbic lobe) comprises several phylogenetically older structures centered around the brainstem:

1. **Cingulate gyrus**
2. **Parahippocampal gyrus**
3. **Hippocampus (hippocampal formation)**
4. **Amygdaloid complex**
5. **Parts of Hypothalamus**
6. **Nucleus accumbens** (part of ventral striatum)
7. **Orbitofrontal cortex**
The Limbic System

• The **Cingulate gyrus** (CG) lies on the medial aspect of the cerebral hemisphere, above the *Corpus callosum*, from which it is separated by the *Sulcus of corpus callosum*

• CG is limited superiorly by the **Cingulate sulcus**; inferiorly, it is contiguous with *Indusium griseum* (a thin layer of primitive cortex covering the *Corpus callosum*)
The Limbic System

- The **Hippocampus** is located in the depth of the temporal lobe; on coronal sections, its shape resembles that of a sea horse, and this is where it derives its name from.
- The Hippocampus consists of the following sub-structures: *Dentate gyrus, Hippocampus proper (Amon’s horn), Subiculum* and *Entorhinal cortex*.
- The **Uncus** is the anterior, enlarged portion of the Hippocampus; the tail of the Dentate gyrus separates the inferior portion of the Uncus into the *Uncinate gyrus* (anterior) and *Intralimbic gyri* (posterior).
- Note: the Hippocampus plays a major role in encoding of long-term memory, and contrary to earlier views, does not appear to participate significantly in the processing of emotions.
The Limbic System

- The **Amygdaloid complex** (AC) represents a group of subcortical nuclei located just in front of the *Hippocampus*

- The AC receives input from subcortical areas concerned with the somatic expression of emotions (Hypothalamus and brain stem nuclei), via the *Basolateral nucleus*, and sends output to cortical areas concerned with the cognitive aspects of emotion via the *Central nucleus*
The Limbic System

- The **Nucleus accumbens** (NACC) is located at the convergence between the head of the *Caudate nucleus* and *Putamen*, just lateral to *Septum pellucidum*
- The histology and connectivity pattern of the NACC is very similar to that of the other components of the Striatum
- The majority of the NACC neurons are GABA-ergic medium spiny neurons
- Major input to the NACC originates in the *Ventral tegmental area* (Dopaminergic), *prefrontal cortex*, *Amygaloid complex* and *Hippocampus*
- The NACC projects back to the *prefrontal cortex* via the *Dorsomedial thalamic nucleus*
- The NACC is thought to play a major role in *reward* and addiction; *the state of activity in the NACC appears to be regulated by the dopaminergic projections from the Ventral Tegmental Area*
The Limbic System

- The **Orbitofrontal cortex** (OFC) lies just above the orbital roof, at the base of the frontal lobe.
- The **olfactory** and the **orbital sulci** divide the surface of the OFC into four gyri: **Gyrus rectus, Medial orbital gyrus, Anterior orbital gyrus, Posterior orbital gyrus** and **Lateral orbital gyrus** (Note: there are many anatomic variants of the OFC, which may substantially differ from the above description).
