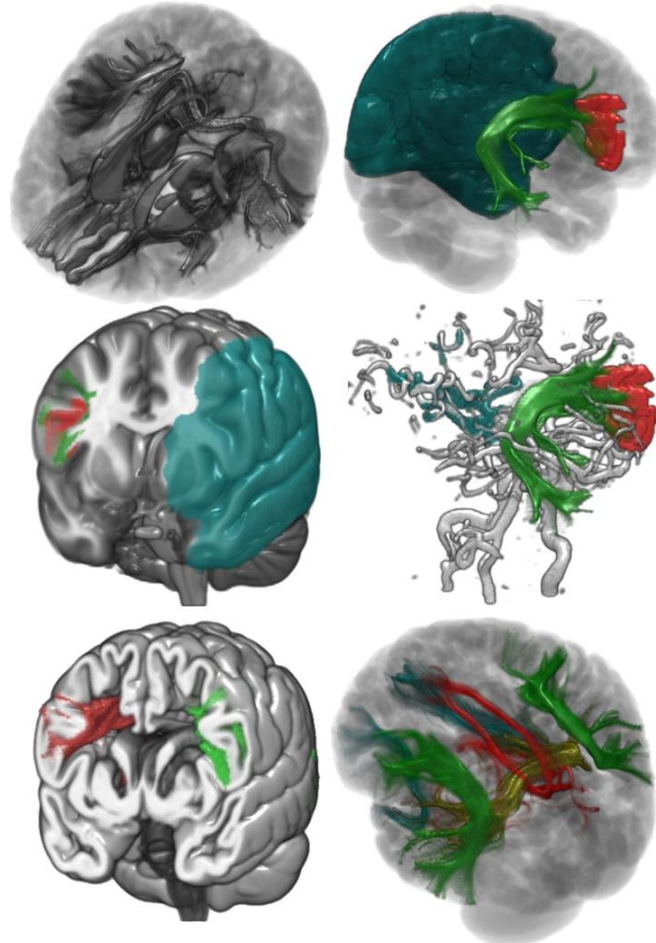


Connectopedia

Version 2.0



Interactive Atlas of Humain Brain

Functions, Connectomics and Vasculature

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Acknowledgment : *Pr Chris Rorden, McCausland Center, University of South Carolina, USA*

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I. General Overview

Connectopedia is an interactive atlas of human brain structures, functions and vasculature, using brain connectomics to assess functional pathways of the tasks performed by the brain.

Connectopedia is linked with the DPTOOLS package from version 6 and above, and is distributed standalone, free of charge, for academic purposes only, with BSD licensing.

Connectopedia was coded using C++ and Delphi, with OpenGL 2D and 3D reconstructions for volume rendering purposes (thanks to the Chris Rorden MRICroGL sources), and is compatible with NIFTI files. Connectopedia requires Microsoft Windows Vista or Mac OSX 10.8 and above, a minimum of 4 GB of RAM (8 recommended), and an OpenGL capable graphic card. A display capable of 1080p or two displays are recommended.

Connectopedia uses the 152 MNI T1 and Cortical Areas (116 areas) Atlas templates for 3D rendering of the structural grey matter of the brain. The 58 Fiber bundles were reconstructed from my own brain, using HARDI 60 directions, b value of 1500, and automatically generated and coregistered to the T1 MNI template using DPTOOLS 6.1 and the MedInria 1.9 software suite. The 90 arterial and 54 venous referenced structures were set by manual segmentation on the T1 MNI 152 isotropic 1 mm³ template. Arterial and Venous 3D VR reconstructions were set on TOF and 3D Phase Contrast MR sequences and isotropically 1 mm³ coregistered to the T1 MNI template.

Connectopedia was created to provide to neuroscientists as well as students an easy way of learning, teaching or checking functional neuroanatomy, and is linked to DPTools v6 and above, which was used to study structural and functional connectomics with real time reconstructions and assessment of the brain structural and functional connectoms.

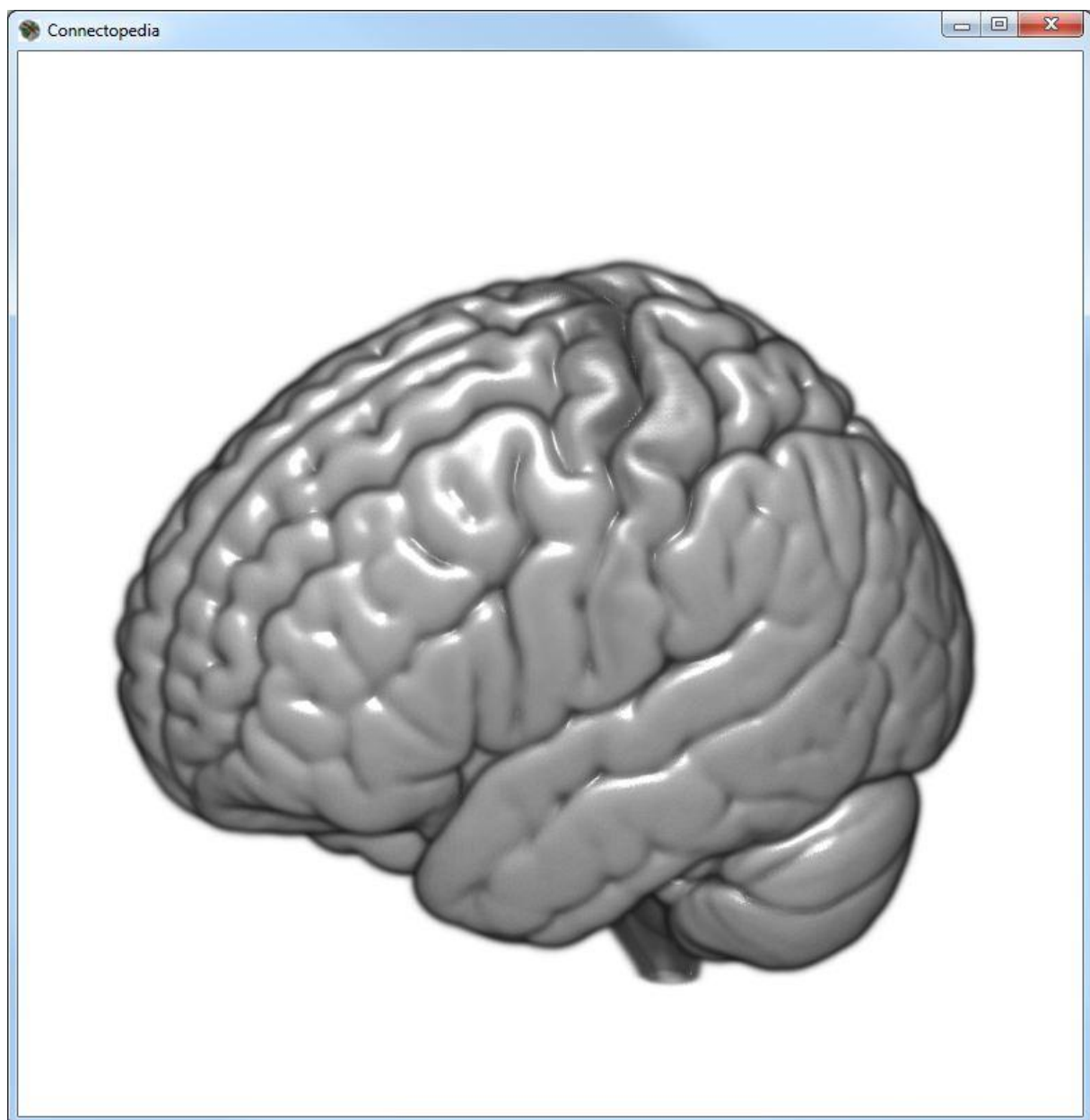
Neuro-functional and vascular knowledge database were set using Wikipedia, and some other references:

1. Bases of Functional Neuroanatomy, Monica Baciú, de Boeck Editions, 2011
2. Fiber Pathways of the Brain, Jeremy Schmahmann, Deepak Pandya, Oxford Editions, 2006

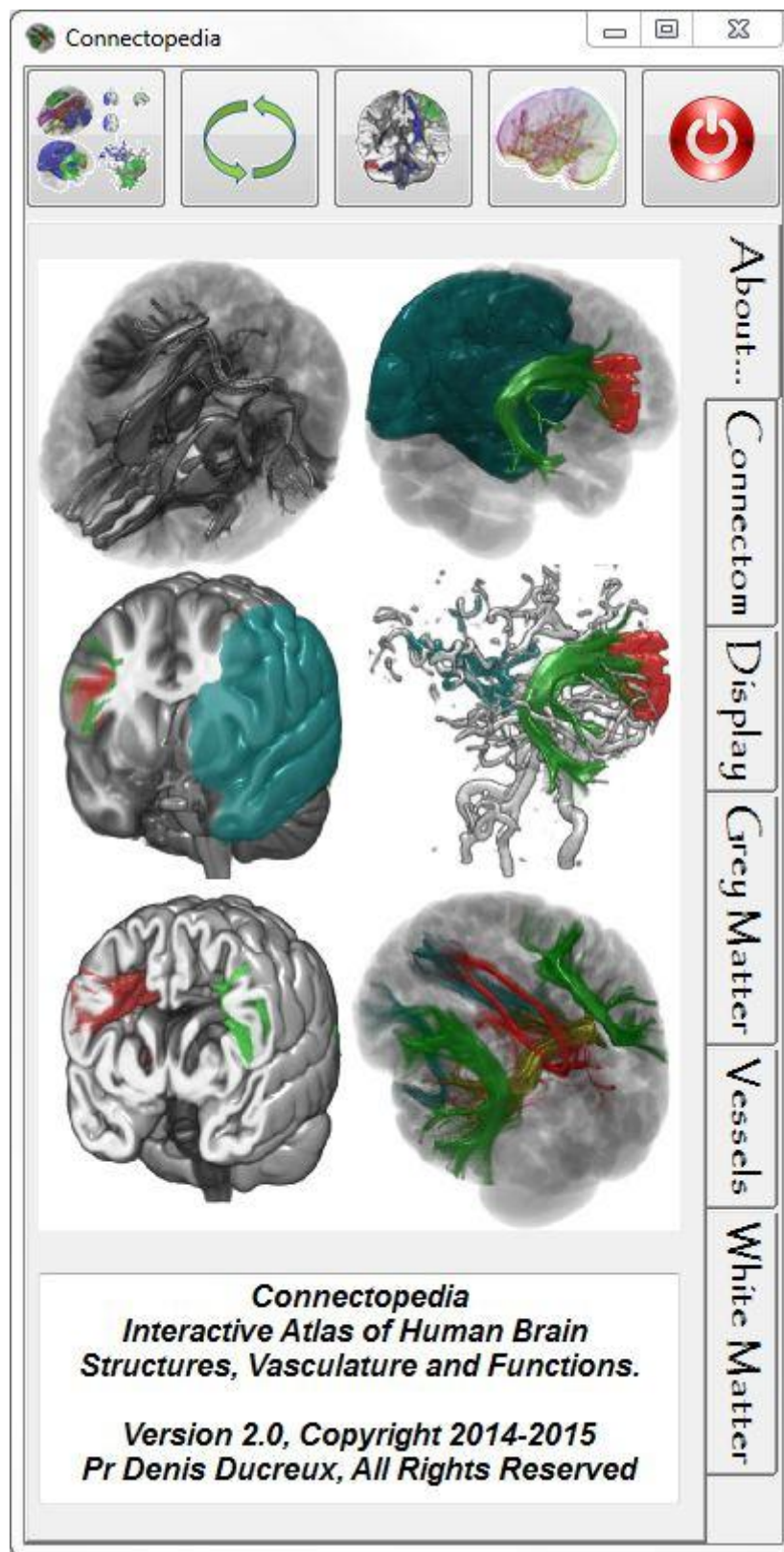
3. Networks of the Brain, Olaf Sporns, MIT Press, 2011
4. Atlas of Human Brain Connections, Marco Catani, Michel Thiebaut de Schotten, Oxford Editions, 2012
5. Diagnostic Imaging Brain, Ann Osborn, Elsevier 2005
6. Brain Vasculature, G. Lazorthes, Masson 1961.

Connectopedia includes :

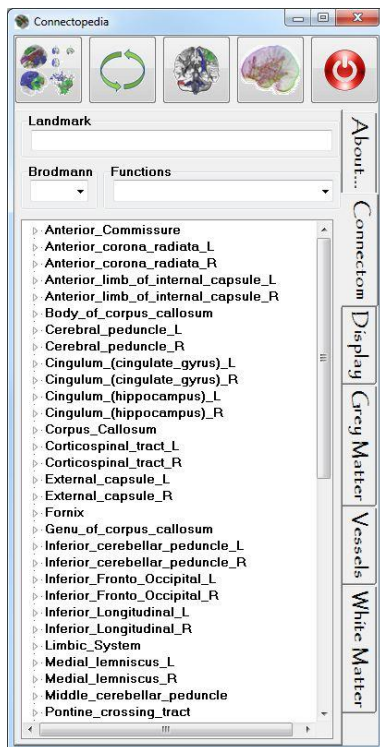
- The **3D Rendering** viewer window of brain cortex (only grey matter), brain (grey and white matter), fiber bundles and vasculature (arteries and veins):



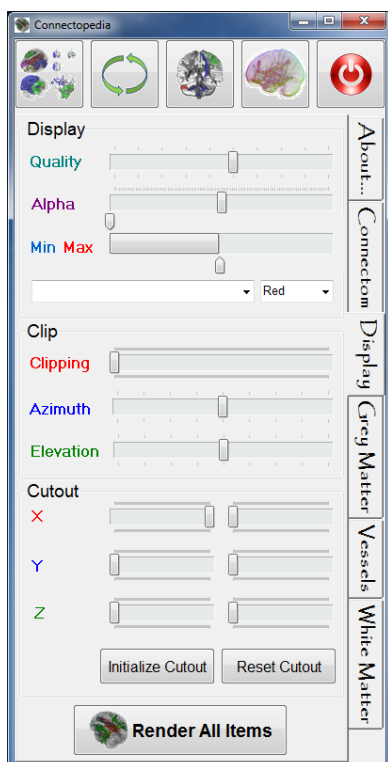
- The **Selector** window with specific buttons and tabs:



* The *Connectom Tab*:



- a brodmann area (BA) selector, with all BA linked to cortical areas and to brain functions
- a brain function (BF) selector linked to the BA selector
- a connectom path selector to select either bundle by bundle, area by area, areas by bundles, or bundles by areas, showing how cortical areas are structurally linked to each other by the fiber bundles, as well as vasculature branches treeview



*The *Display Tab*:

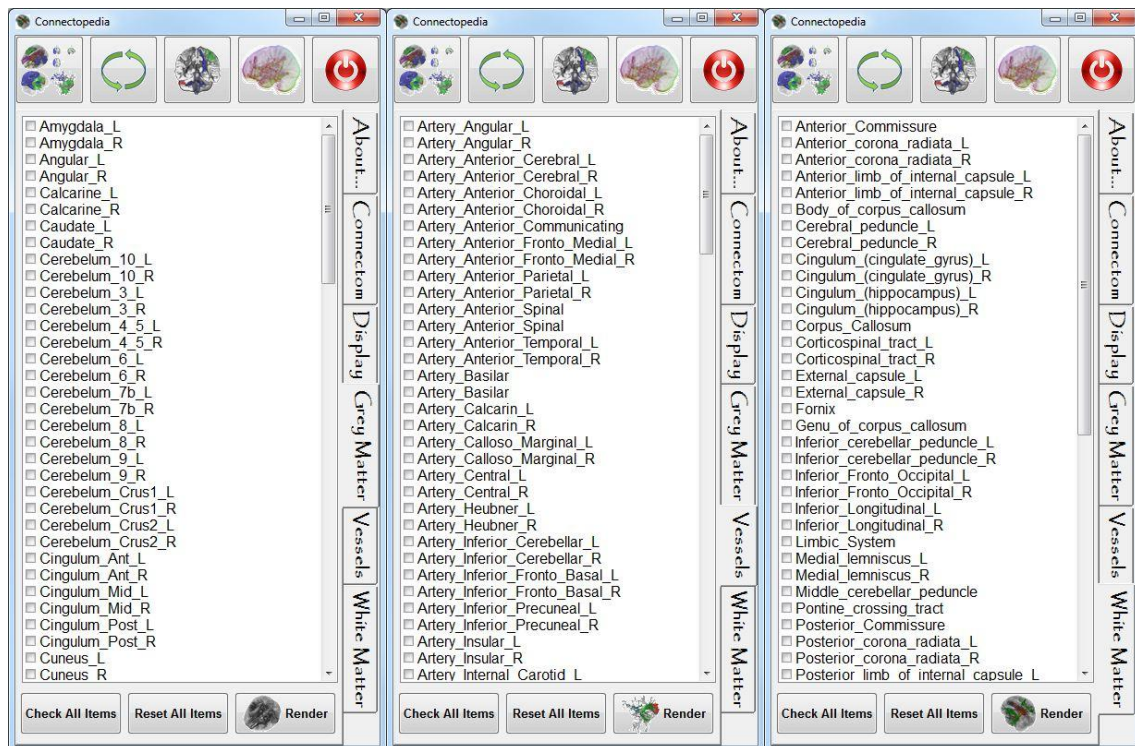
Display settings :

- Quality
- Alpha Blending
- Minimum and Maximum Thresholding
- Items color setting

Clipping and Cutout Tools

“Render All Items” button


*The *Grey Matter, Vessels, White Matter* Tabs:

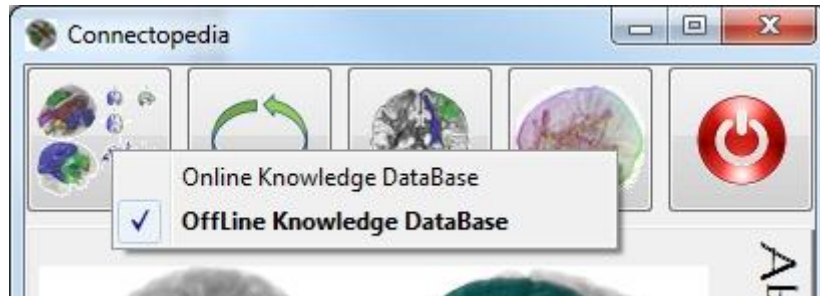






to study or show either cortical areas and/or fiber bundles and/or vessels one by one or by group, sorted by Name or Topology (RC to select sorting type).

Buttons to check, uncheck all items, and to render the selected items in the 3D Render Window.

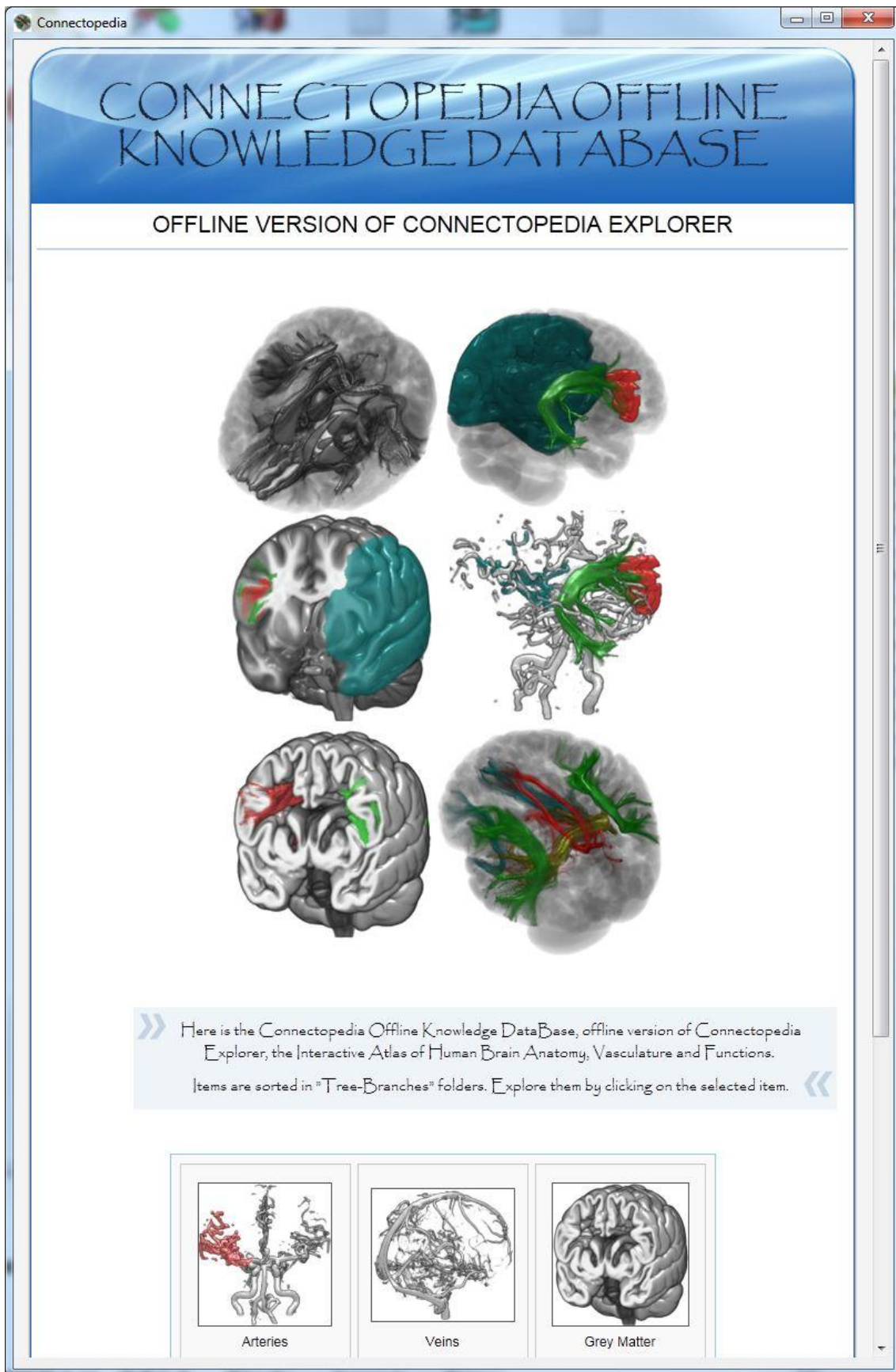
*Functions buttons:

- . the KdB Enabler Button  to enable or disable Preview of the KdB Files, and selecting between Offline and Online KDB (RC on it to select DataBase source):



- . the “Synchronize” Button  to sync Connectopedia and DPTtools
- . The “Tracking Pathways” Button 
- . The “Movie” Button 
- . the “Exit” Button 

- The **Knowledge Database Browser (KDB)** with anatomical and functional descriptions of the grey matter areas, the white matter bundles, and the vasculature, either online if you have a high speed internet connection, or offline.

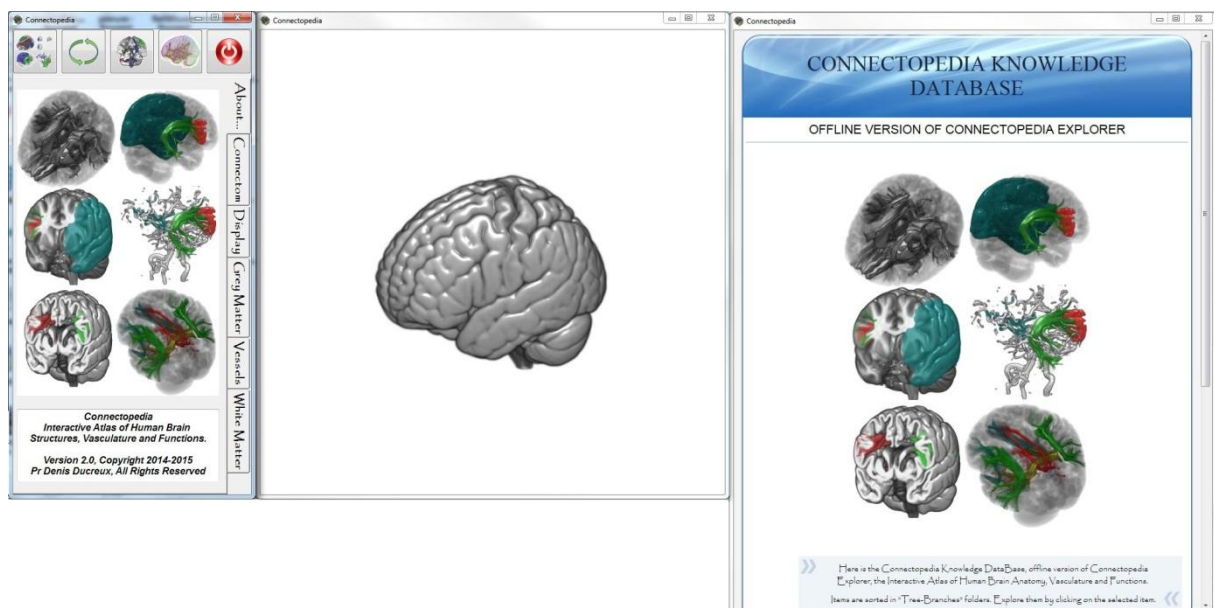


With Connectopedia user can select a fiberbundle, see the cortical areas linked by this bundle to each other, add vasculature to see the vascular territories, and view how the brain is working within this network using the Real Time fMRI Movie Selector.

User can also select two cortical areas and track the pathways linking the two.

When used combined to DPTools, user can automatically identify arterial or venous territory (stroke) and identify damaged brain structures.

All the movies of the brain included in the KdB are showing real time activations, and structural and functional connectomics involved in the selected functional task.



II. Installation

Standalone Connectopedia comes with two distributions, for Microsoft Windows Vista and above, and for Apple OSX 10.8 and above, each either online (lightweight client around 50 MB) or offline (<500 MB).

Requierevements are: minimum of 4GB RAM (8 recommended), 500 Mo (for Windows and OSX Standalone distributions) or 2 GB of free hard disk space (for DPTools distribution), and an OpenGL compatible video card (embedded in chipset e.d. Intel, ATI, nVidia or separate card).

II.I Windows installation:

Download the software “Connectopedia-Install.exe” on the web site and double-click on it to install.

By default, installation directory (\$INSTDIR) will be DPTools related (e.g. C:\DPTools\bin\Connectopedia). One link will be created in the “Start Program” menu as “Connectopedia”. To run the program, just click on this link.

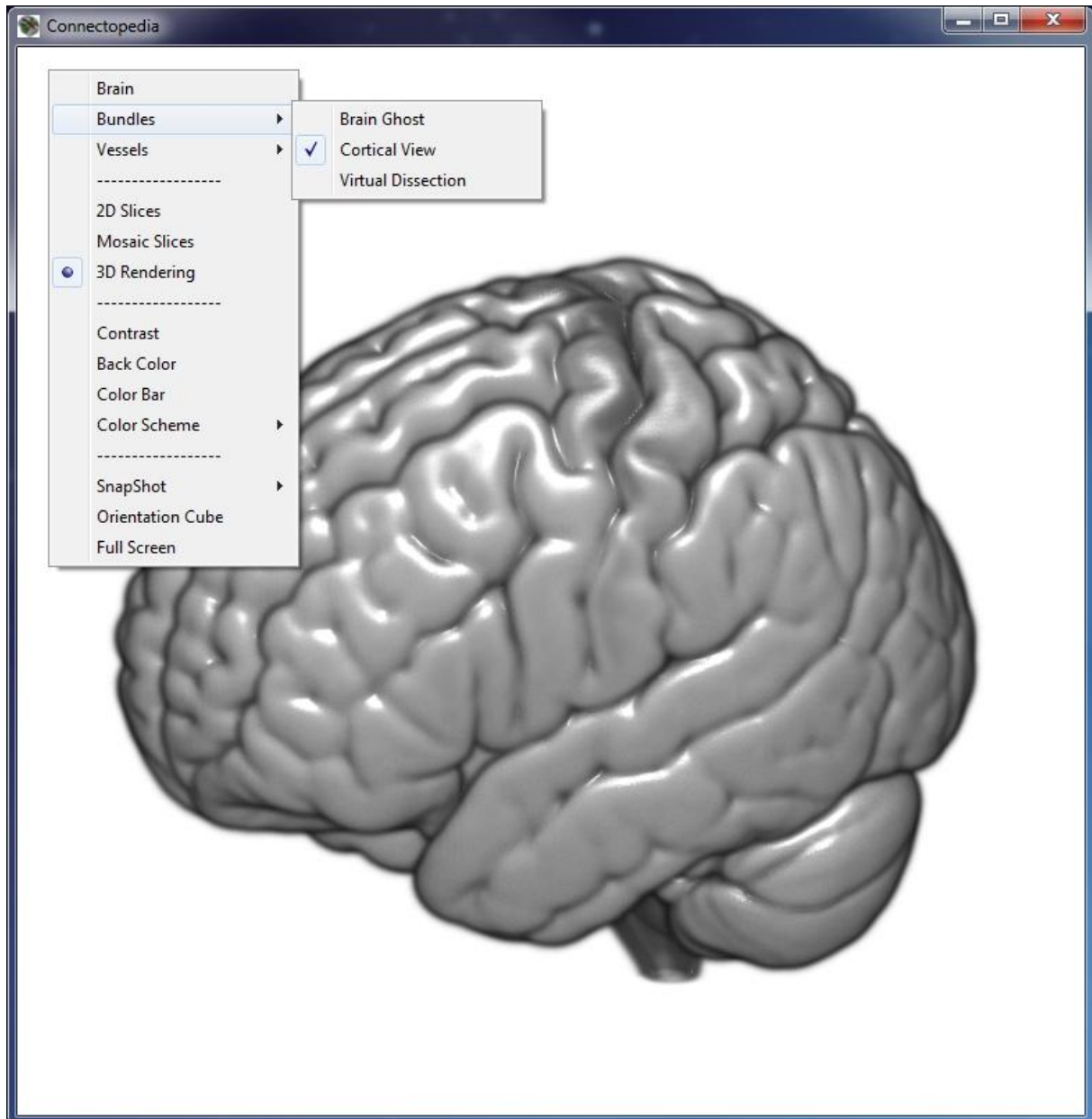
II.II OSX Installation:

Download the software “XConnectopedia.zip” on the web site. When downloaded, double-click on it where it was downloaded (e.d. “Downloads” folder) to unarchive “XConnectopedia”, then run the software by double-clicking on it.

Users of OSX 10.8 and Mavericks (10.9) should change the OSX Gatekeeper properties to be able to run XConnectopedia (see the “Troubleshootings” section of this manual).

III. How to use it ?

Menus are available using the Right button of the mouse (Right Click, RC) in the **3D Rendering Area**, the **Connectoms Path Selector**, the **Clipping Tool Panel** and the **Movie Selector**.

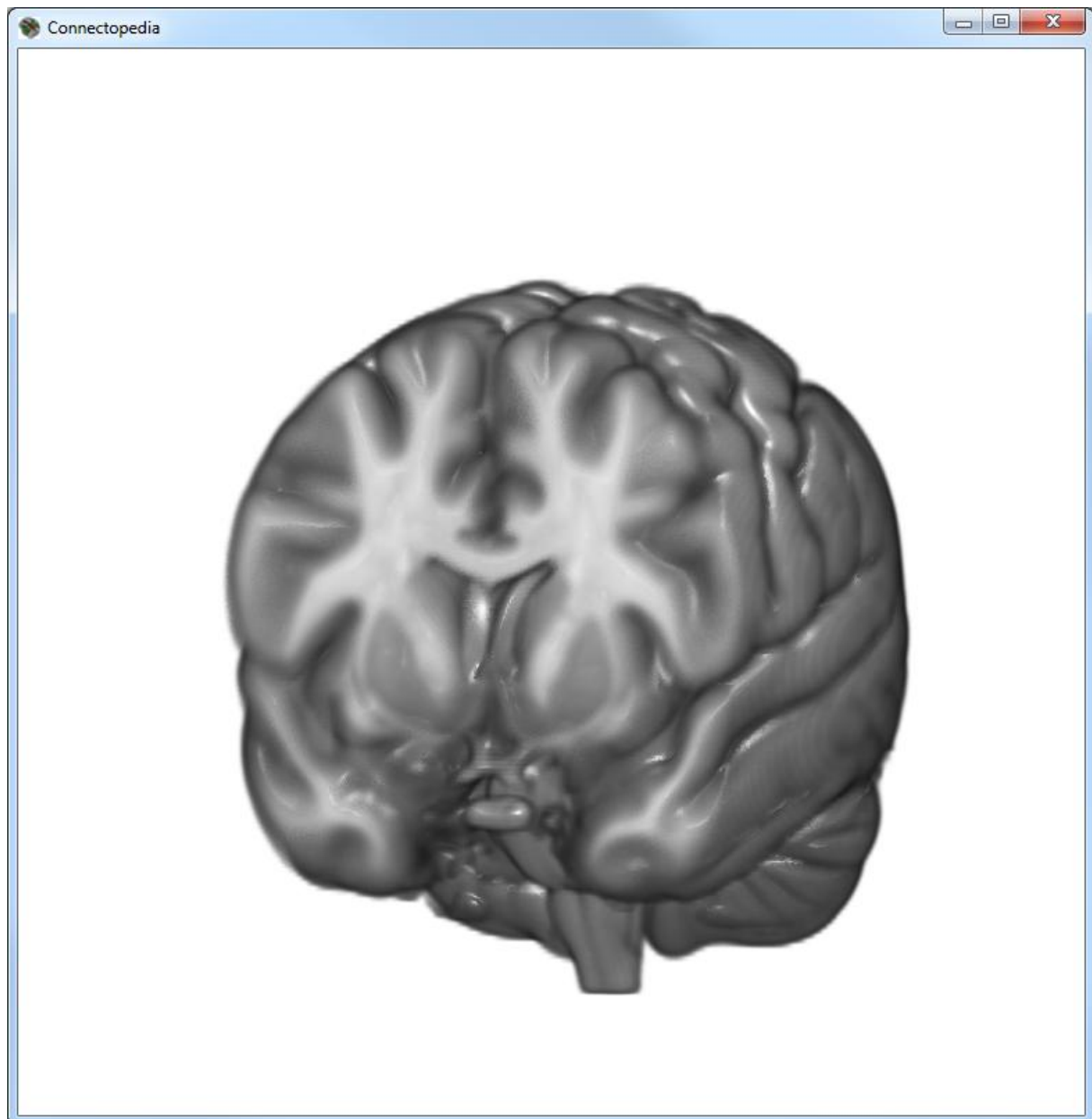


By RC on the **3D Render Window**, you can select either “Brain”, “Bundles” with “Glass Brain”, “Cortical View” and “Virtual Dissection” sub-menus, “Vessels” with “Arteries” and “Veins” sub-menus reconstructions Templates, in 3D, 2D MPR Slices, or 2D mosaic slices.

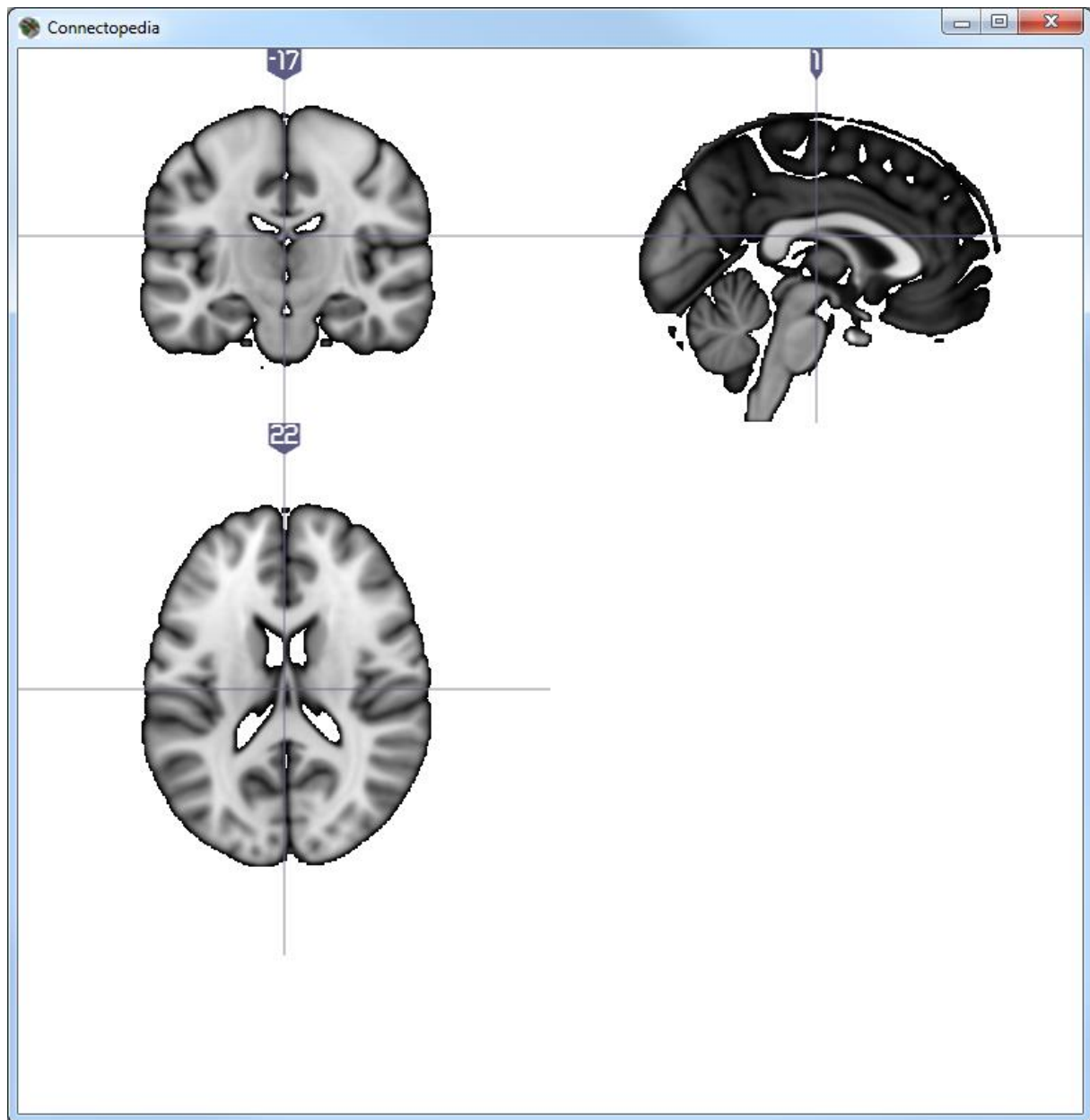
RC is also used to Zoom the 3D rendered view.

Using the Clipping bars below the Display area in Display Tab of the Selector Window, user can perform 2D or 3D clipping reconstructions of the selected Template.

Here is a **3D Cut** using the “Brain” Template:

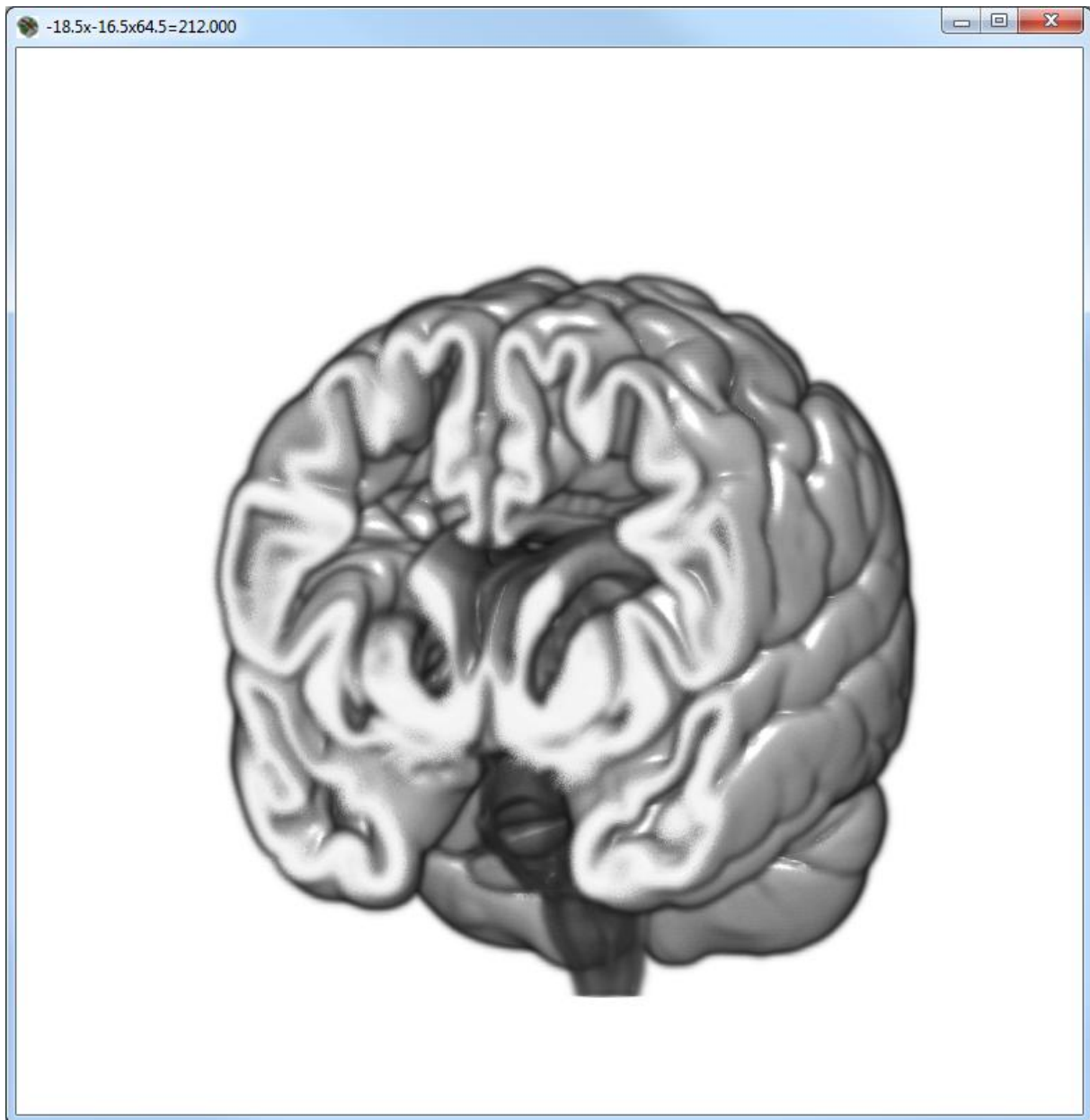


The matching **2D MPR** reconstruction:



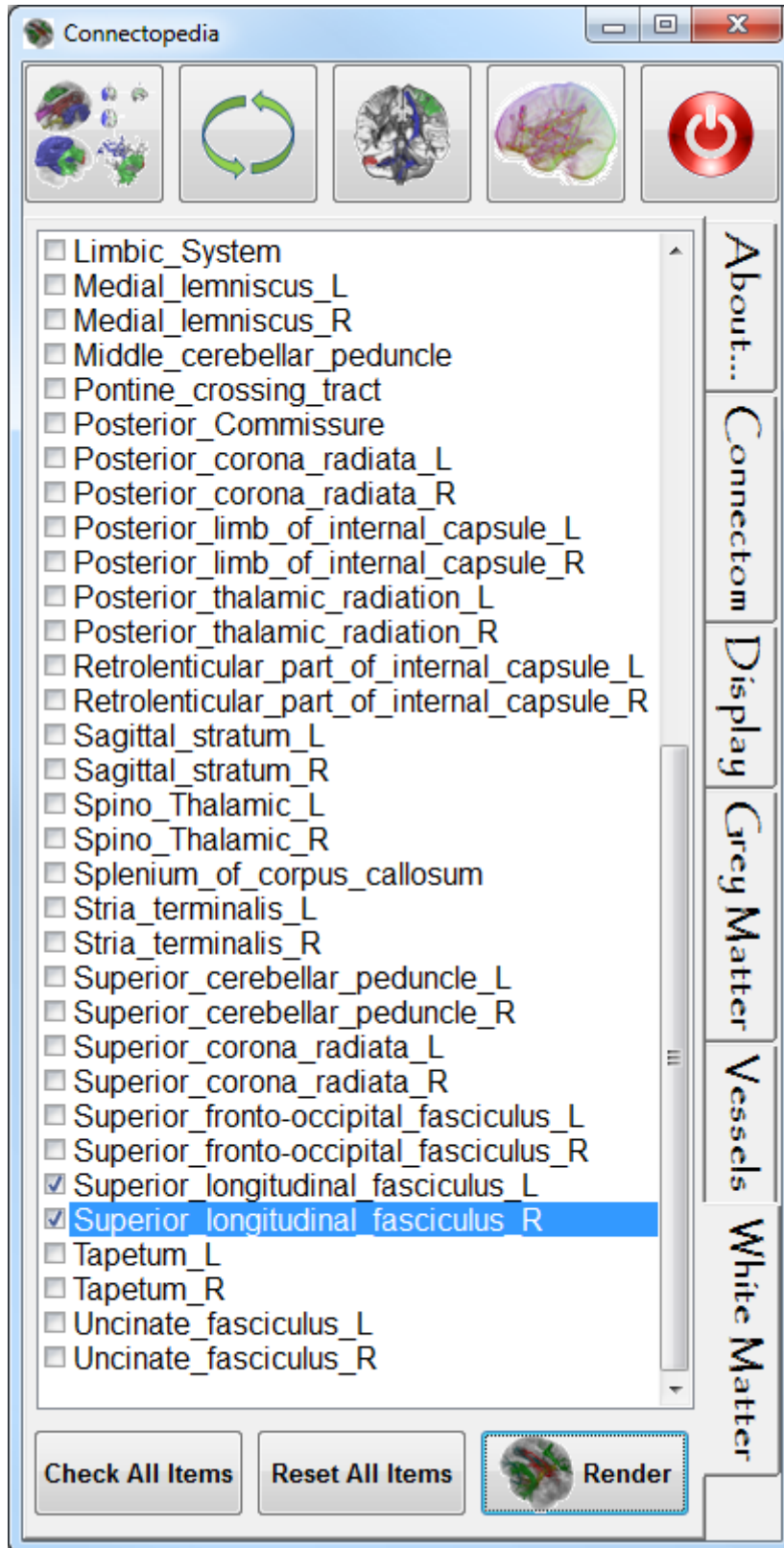
Note that given coordinates in 2D reconstructions are in true MNI coordinates.

Here is a **3D Cut** using the “Cortex” Template (in this template, only grey matter is reconstructed):



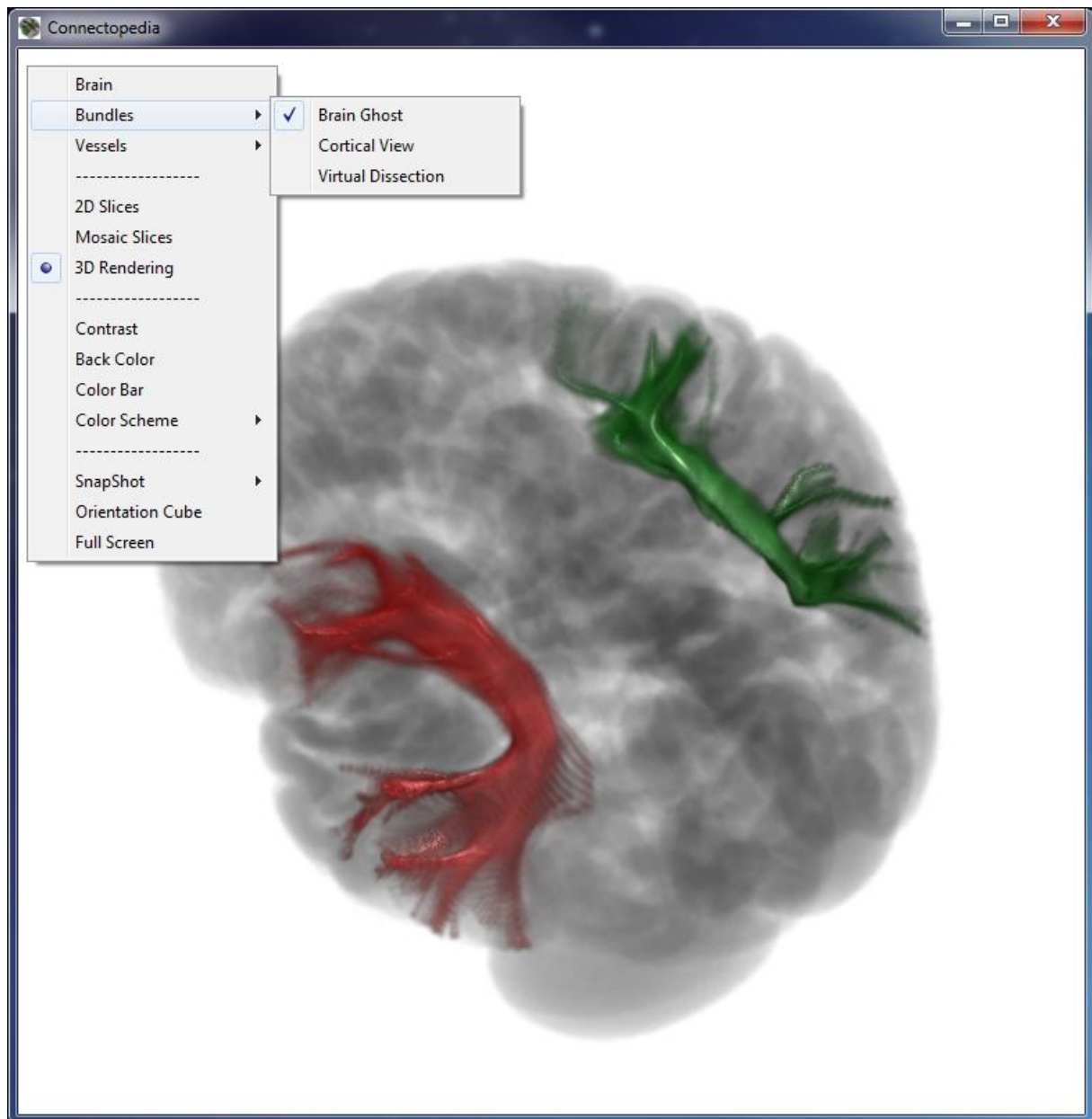
IV. First exercise: Bundles selection

Let's study the both Superior Longitudinal Fasciculi, especially the Arcuate bundles.



First select in the White Matter Tab Selector the matching bundles (« Superior_Longitudinal_Fasciculus_L and _R ») by LC on the small empty square (to deselect it, just relick), then set the “Bundles” Template using RC on the 3D rendering area, then press the Render Button.

Choose the “Brain Ghost” sub-menu item by RC on the 3D Render window.

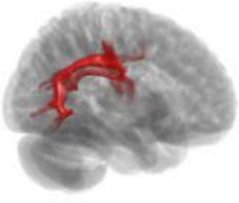


When selected, the KDB Window displays anatomo-functional informations related to the selected bundle or cortical area.

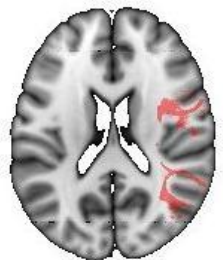
Connectopedia

CONNECTOPEDIA OFFLINE
KNOWLEDGE DATABASE

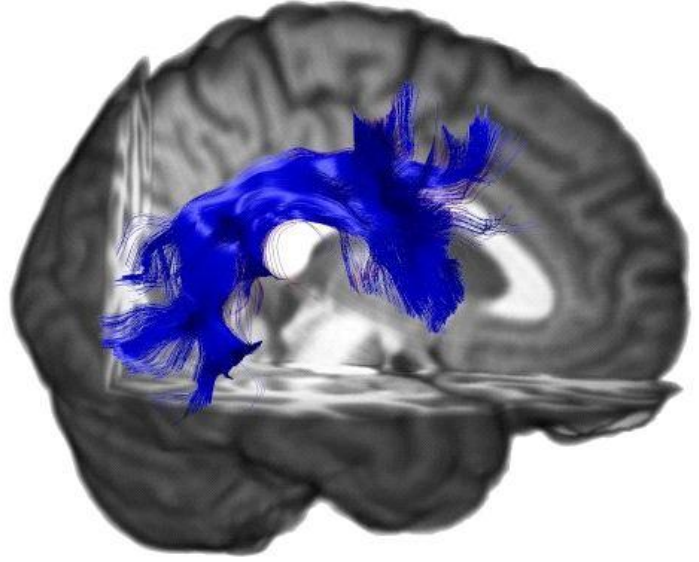
SUPERIOR LONGITUDINAL FASCICULUS



SUPERIOR LONGITUDINAL FASCICULUS
AXIAL SLICES



SUPERIOR LONGITUDINAL FASCICULUS



The superior longitudinal fasciculus (also called the superior longitudinal fascicle or SLF) is a pair of long bi-directional bundles of neurons connecting the front and the back of the cerebrum. Each association fiber bundle is lateral to the centrum ovale of a cerebral hemisphere and connects the frontal, occipital, parietal, and temporal lobes. The neurons pass from the frontal lobe through the operculum to the posterior end of the lateral sulcus where numerous neurons radiate into the occipital lobe and other neurons turn downward and forward around the putamen and radiate to anterior portions of the temporal lobe.

Anatomy

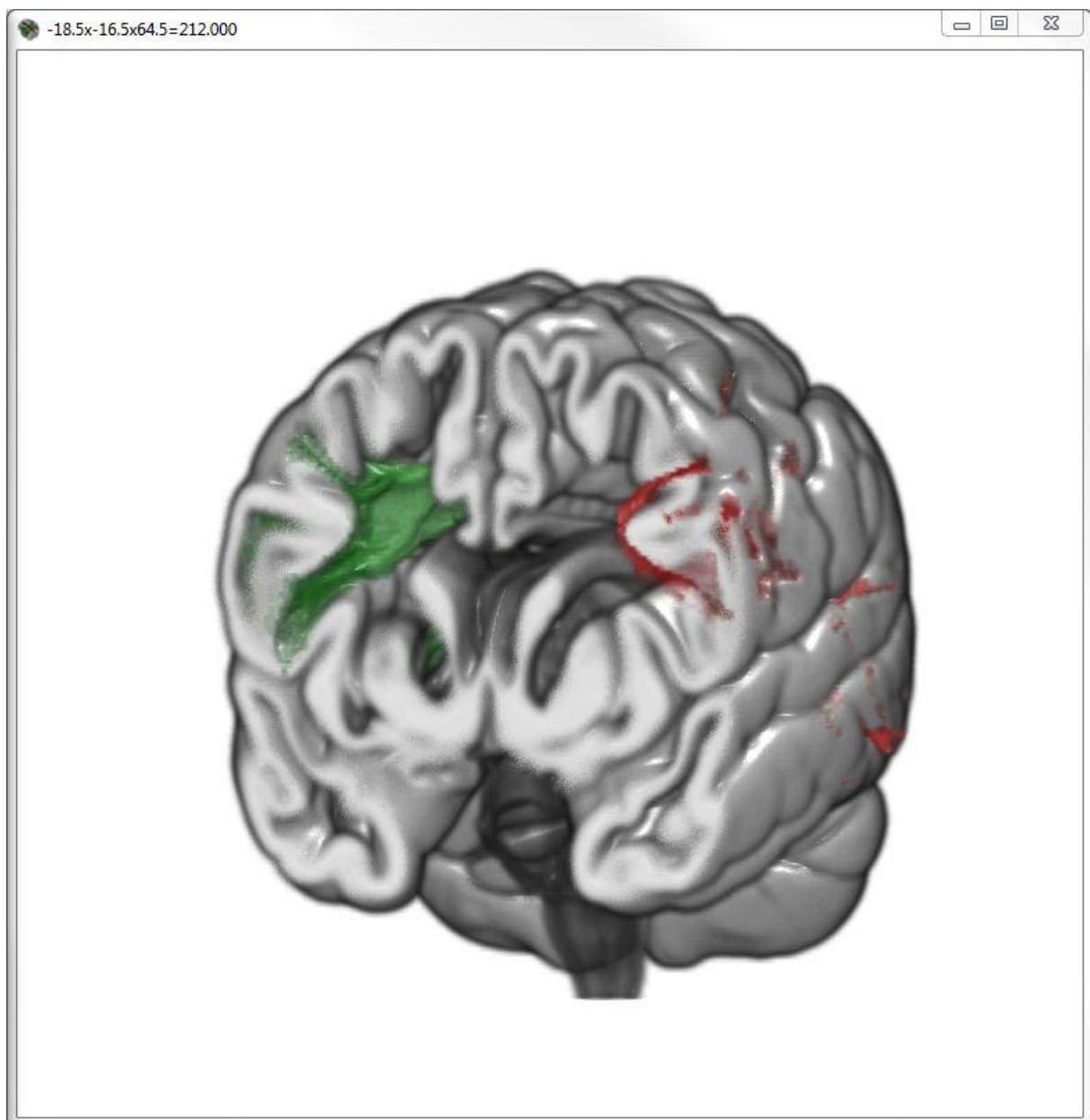
The SLF is composed of four distinct components SLF I, SLF II, SLF III, and arcuate fascicle (AF). In humans, these four components are bundled together although they are functionally separate. In non-human primates, the SLF and AF are anatomically separate and have separate trajectories.

SLF I

SLF I is the dorsal component and originates in the superior and medial parietal cortex, passes around the cingulate sulcus and in the superior parietal and frontal white matter, and terminates in the dorsal and medial cortex of the frontal lobe (Brodmann 6, 8, and 9) and in the supplementary motor cortex (M II).

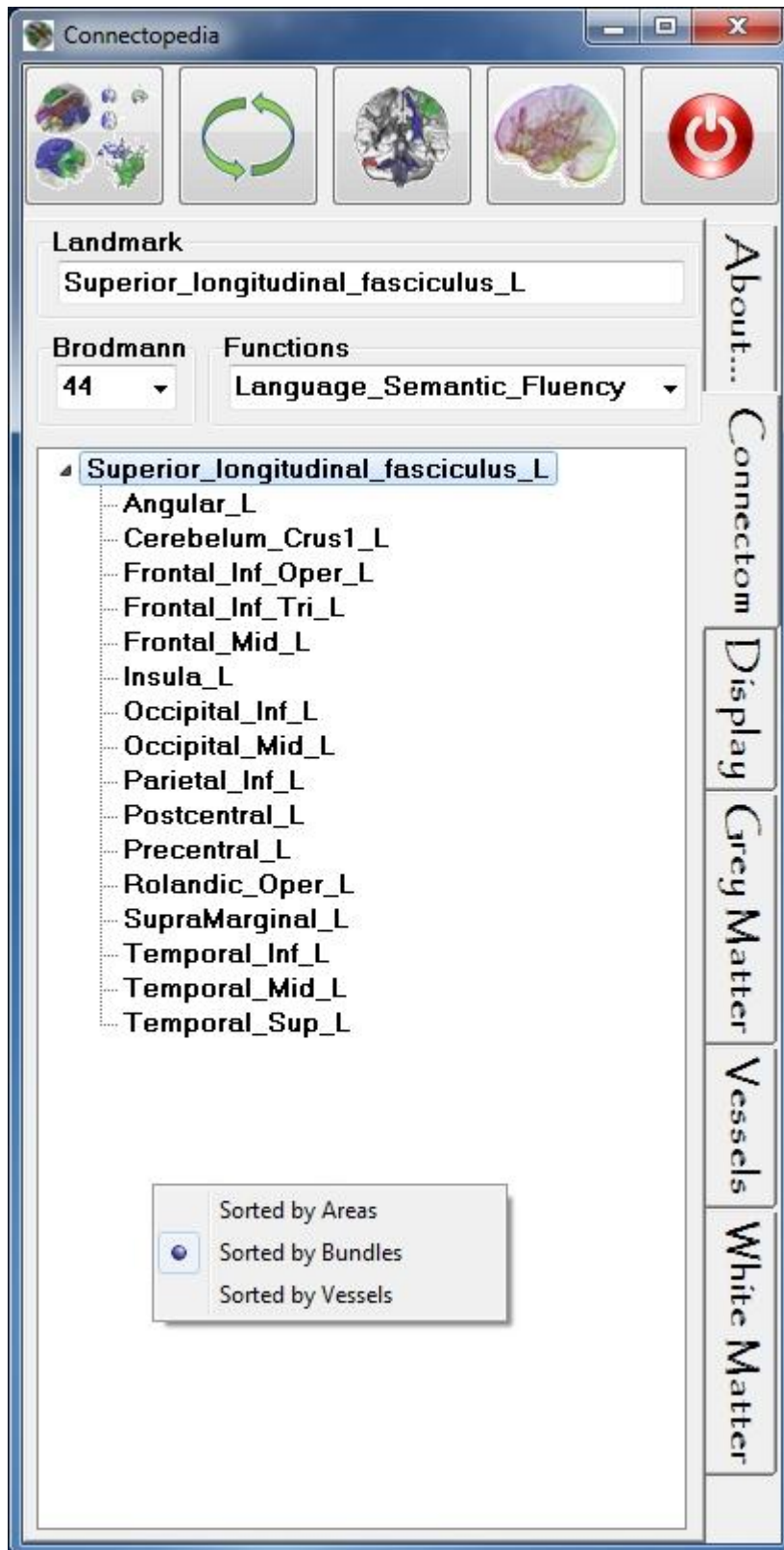
18

The selected bundles can be viewed with the “Cortex” Template in 3D VR mode using a **3D Cut** clipping:



By LC in the Connectom Tab Selector on a cortical area (e.g. « Frontal_Oper_Inf_L »), Brodmann areas referring to the selected cortical area are displayed in the BA selector.

You can select between all the displayed BA by Left Clicking on the **BA Selector**:



Informations in the **Connectom Tab** are restricted to the selected bundle.

By LC on the triangle ▲, a Connectoms Treeview displays all the cortical areas linked to each other by the selected bundle. You can sort these either by Areas, Bundles or Vessels by RC on the Connectom Path Selector and selecting the menu item.

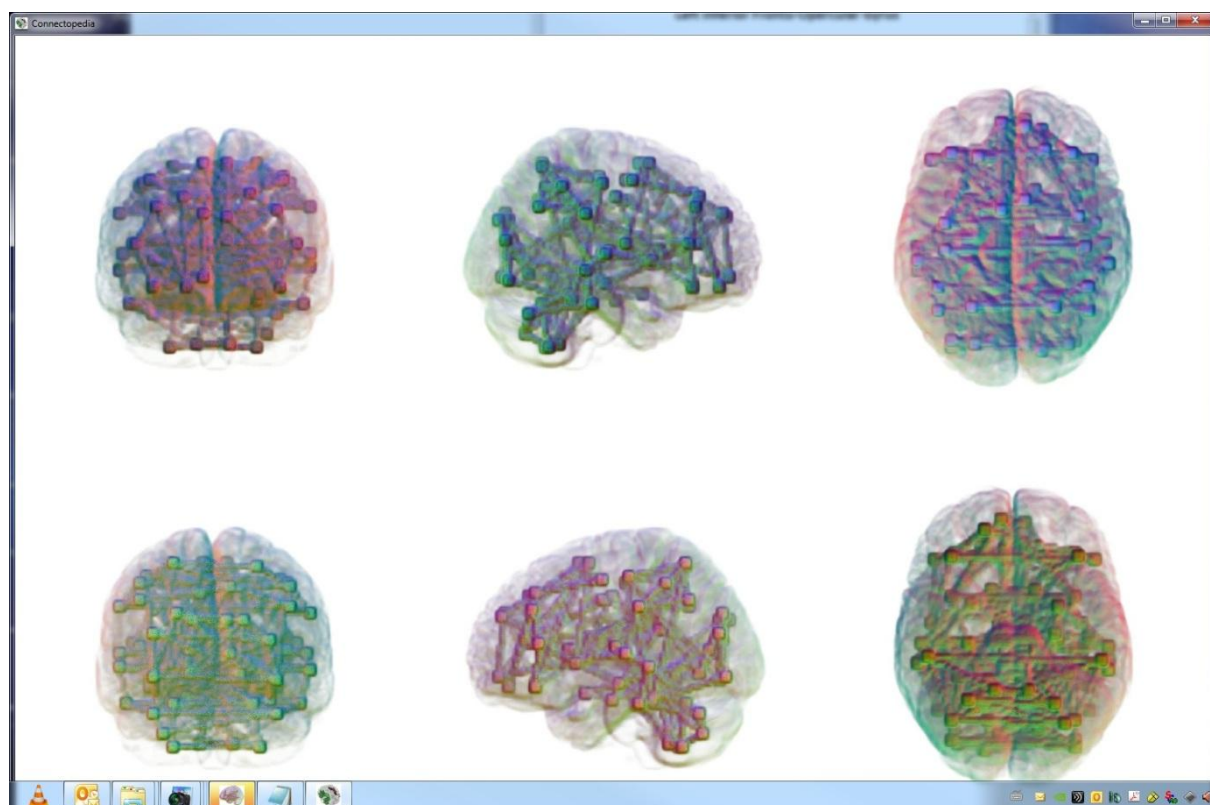
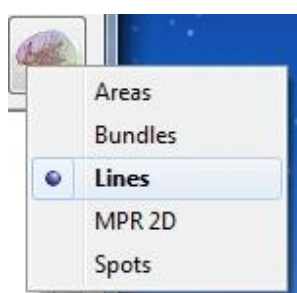
On the right side of the **BA Selector** is the **BF Selector**. When selecting a specific BA, functions are listed in the **BF Selector**, and can be selected by LC on it (here BA « 44 », and Function: « Language_Semantic_Fluency »).

When the function is selected, movies showing the real time activation of the brain can be

displayed by LC on the **Movie Viewer Button**

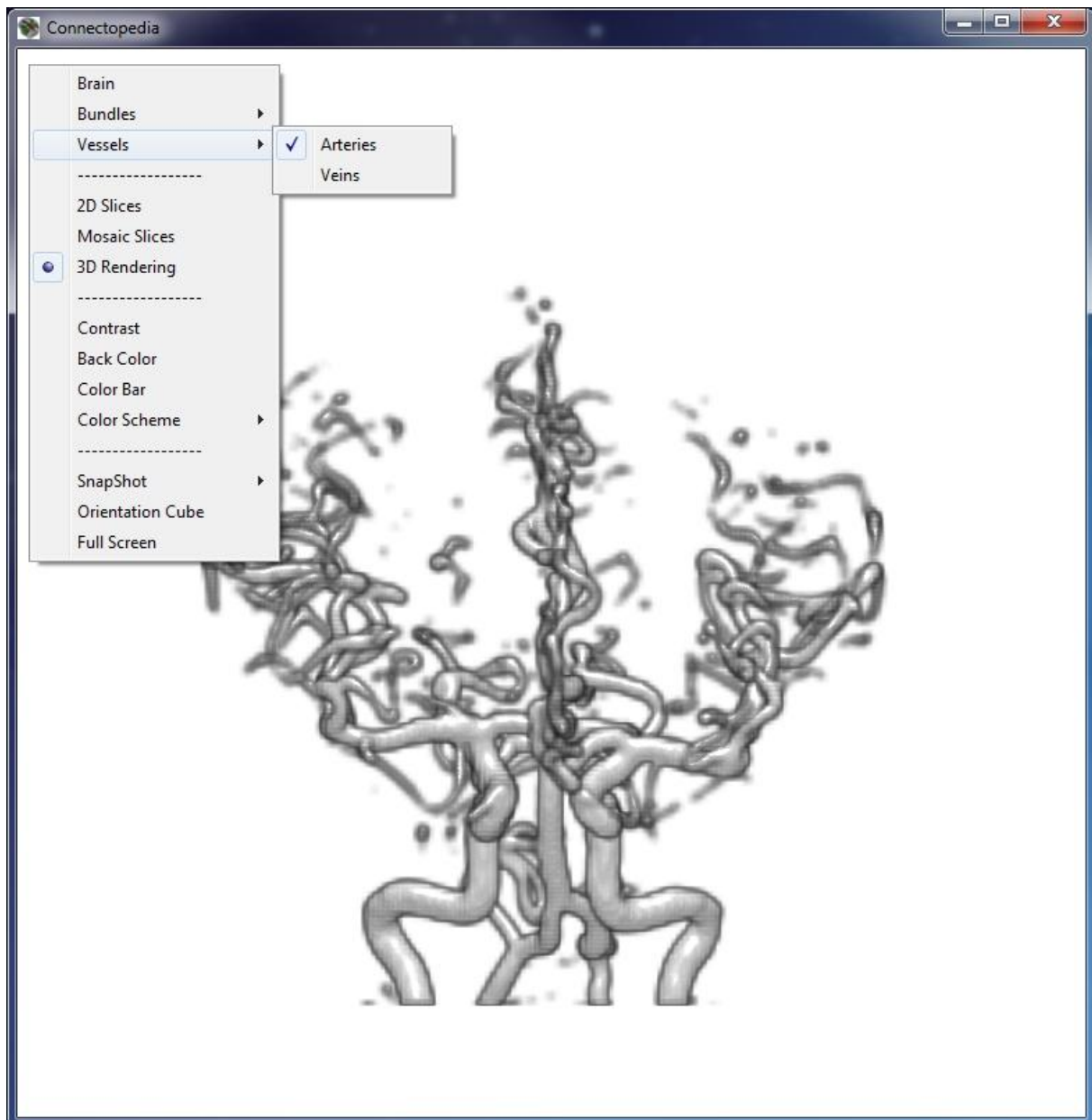


User can choose between “Areas”, “Lines”, “Bundles”, “Spots”, and “MPR 2D” movies, showing the brain connectivity in real time:

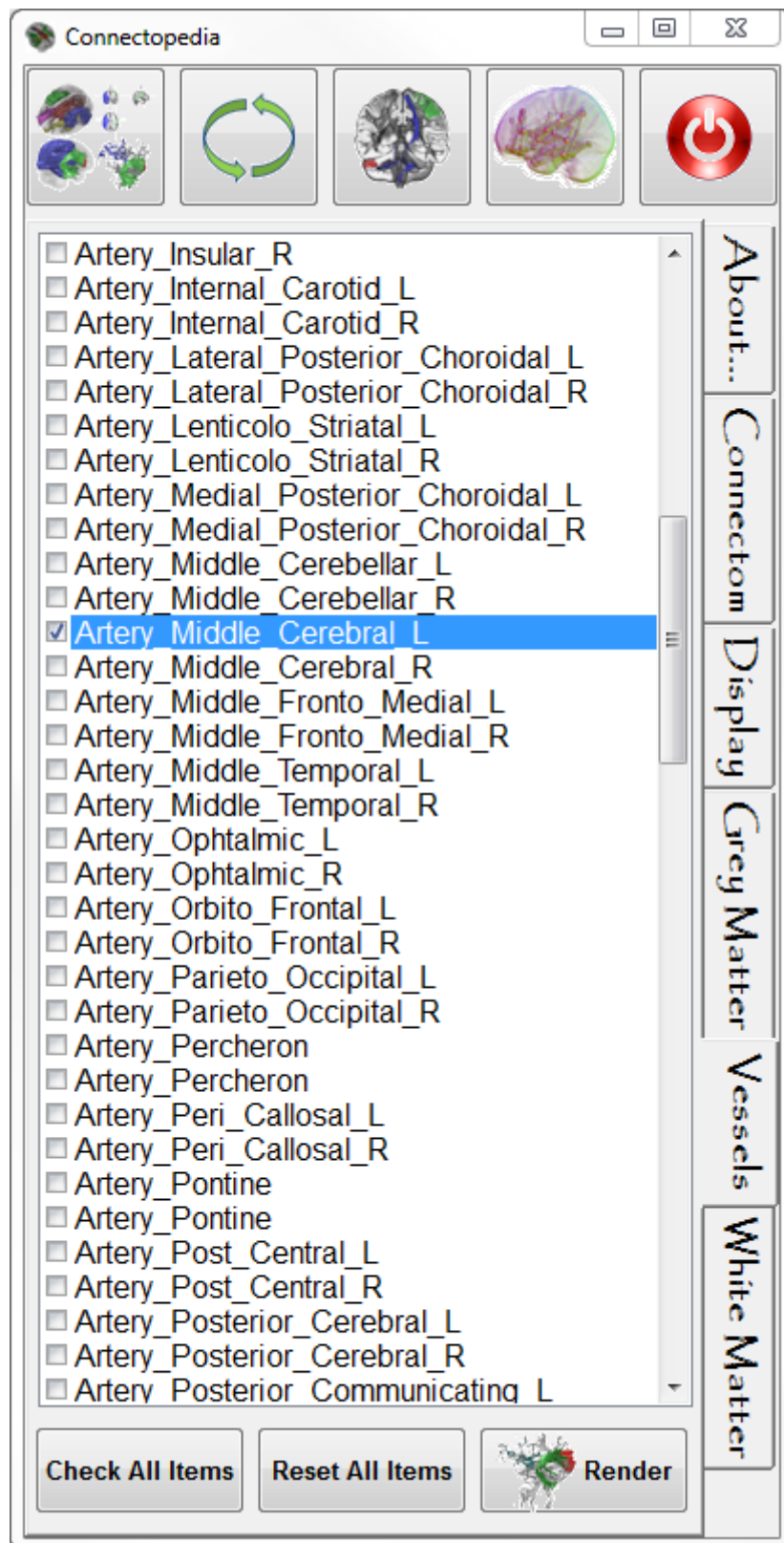


V. Second exercise: Bundles and Arteries

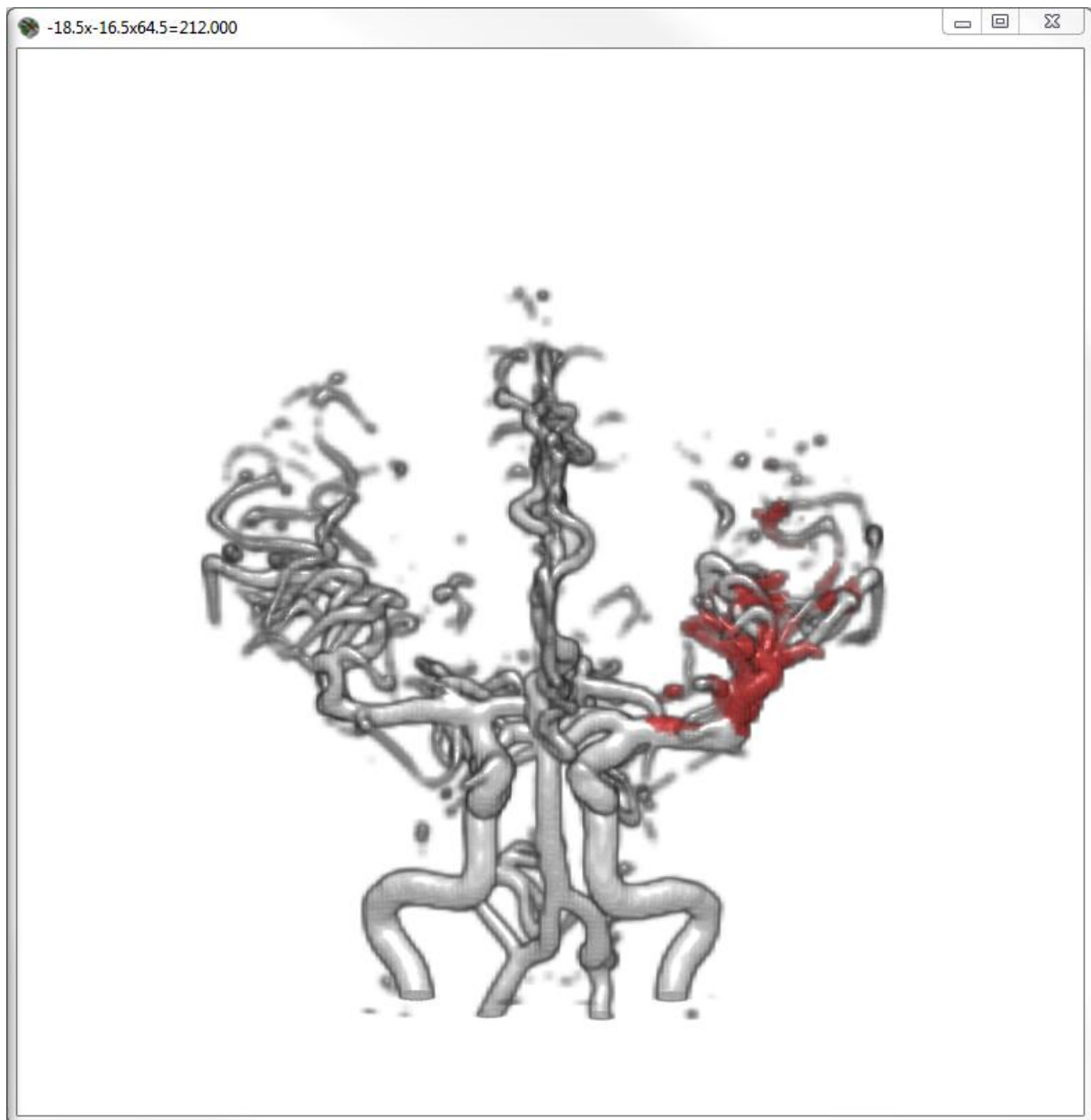
Connectopedia includes a vascular knowledge database of arterial and venous structures. User can reconstruct brain arteries using the “Arteries” Template of the 3D rendering window:



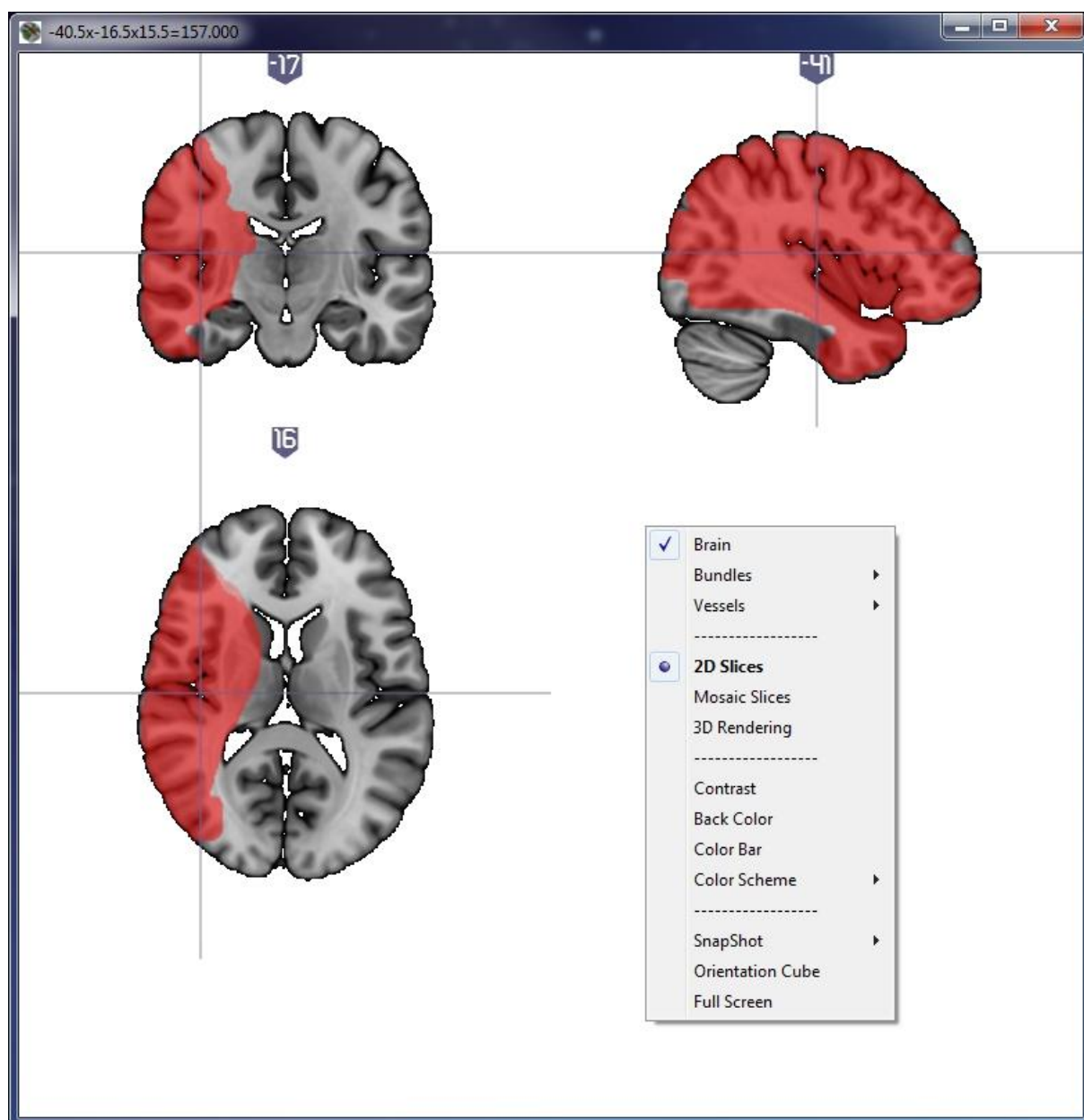
Let's now study the Left Middle Cerebral Artery combined with the Right Superior Longitudinal Fasciculus.



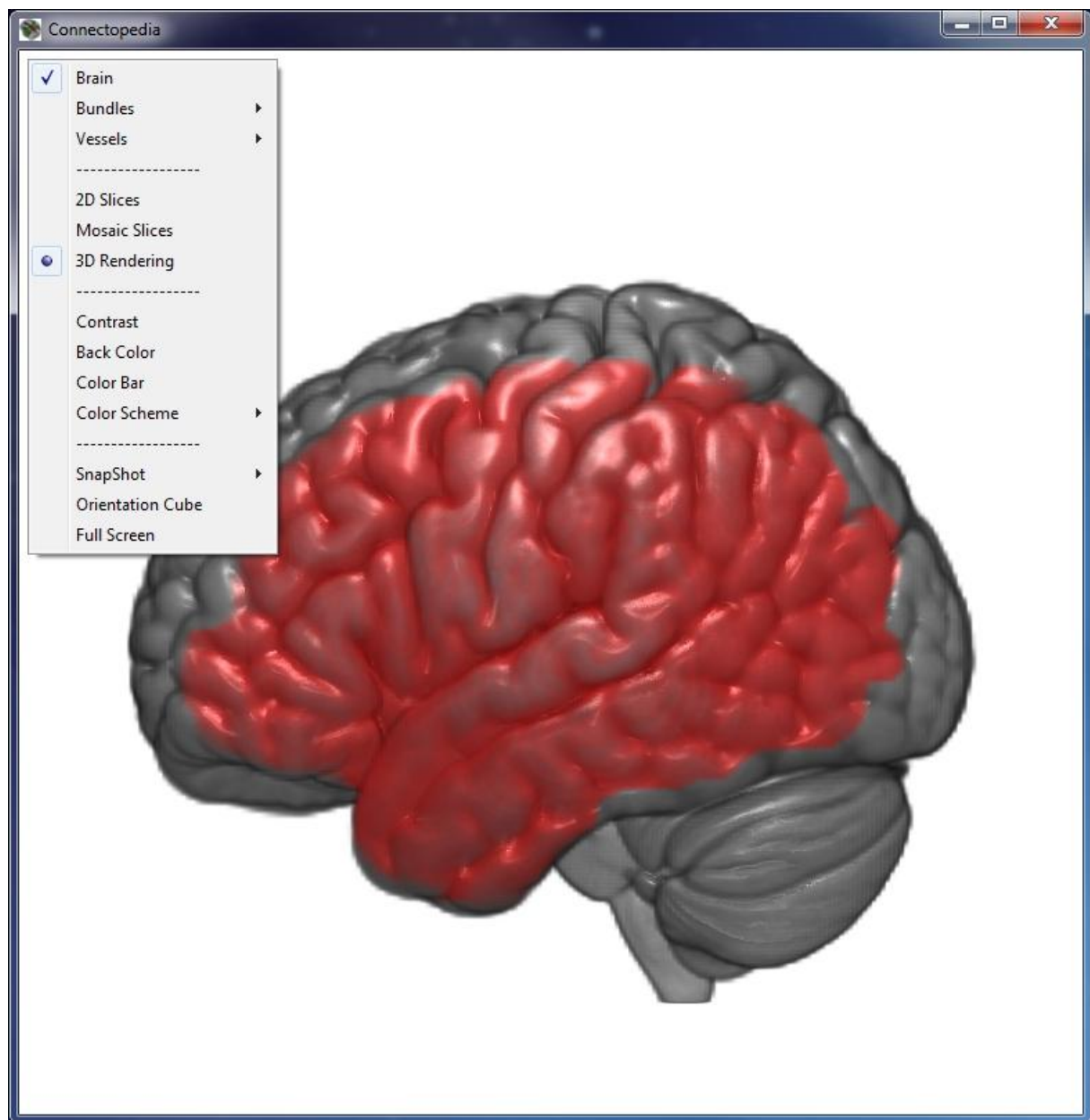
First select in the **Vessels Tab Selector** the matching artery (« Artery_Middle_Cerebral_L ») by LC on the small empty square (to deselect it, just LC again), then set the “Arteries” Template using RC on the 3D rendering area, then press the Render Button.



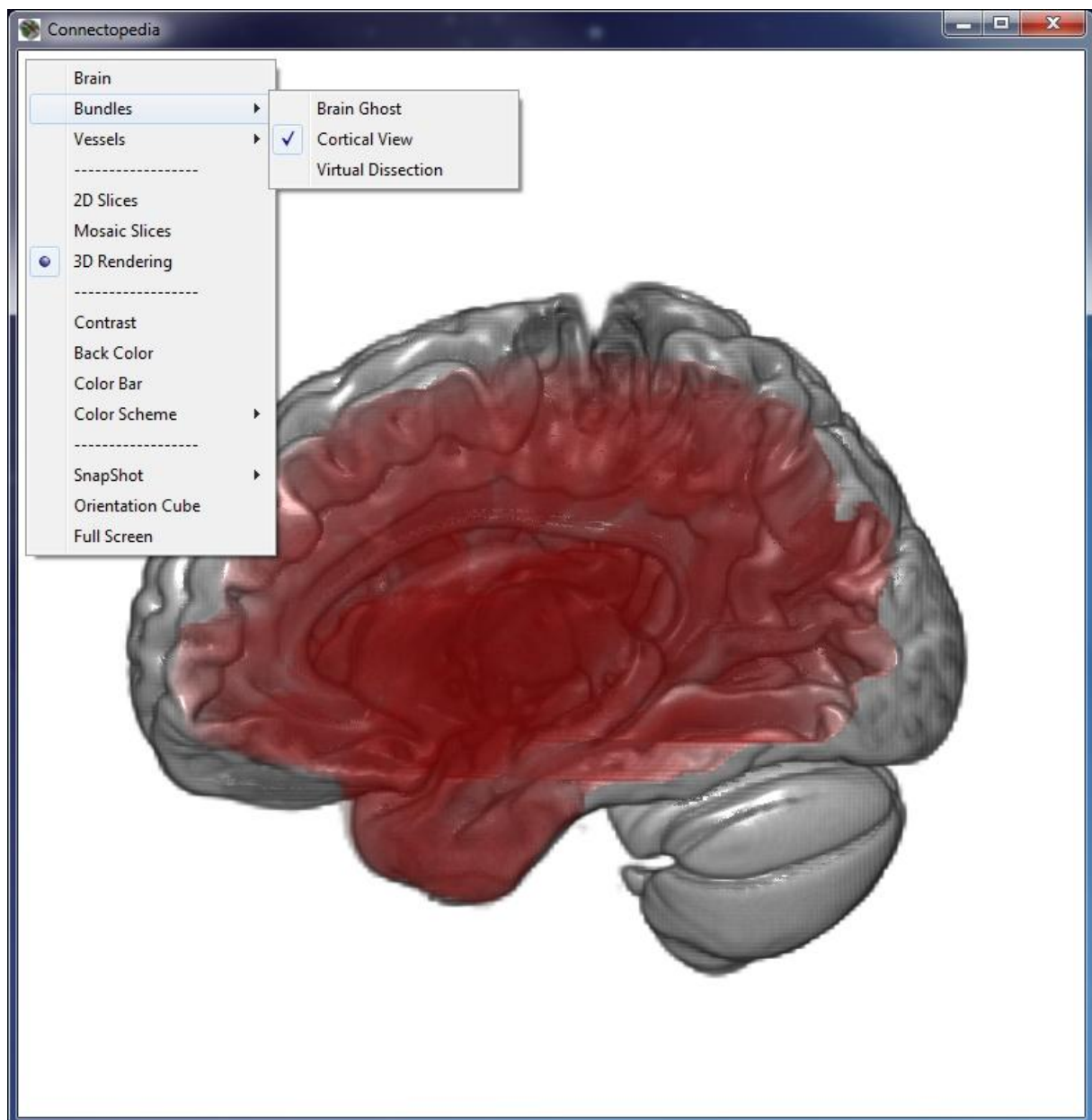
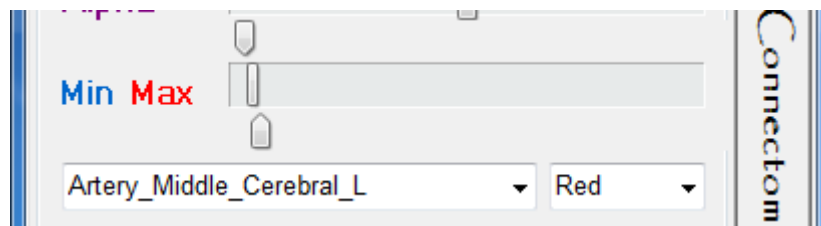
Let's now have a look at the 2D Slices of the Left MCA arterial territory. RC on the 3D Rendering area, select « 2D Slices » and also select the « Brain » Template:



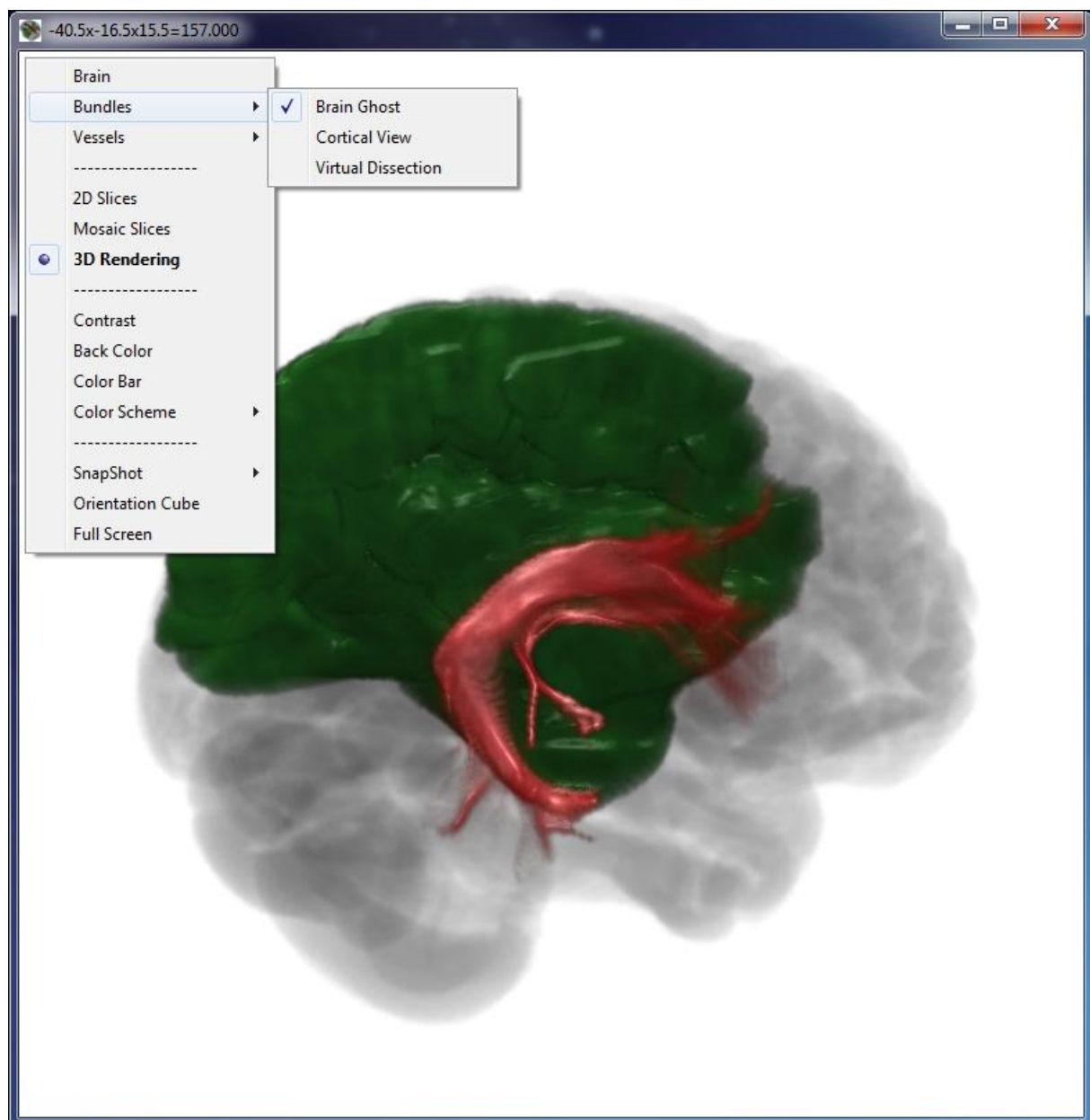
Now have a look at the 3D VR reconstruction of this arterial territory:



In the “Cortical View” sub-menu item of the “Bundles” Template, with “Display Settings” set to High Min and Low Max, some transparent view of the arterial territory:

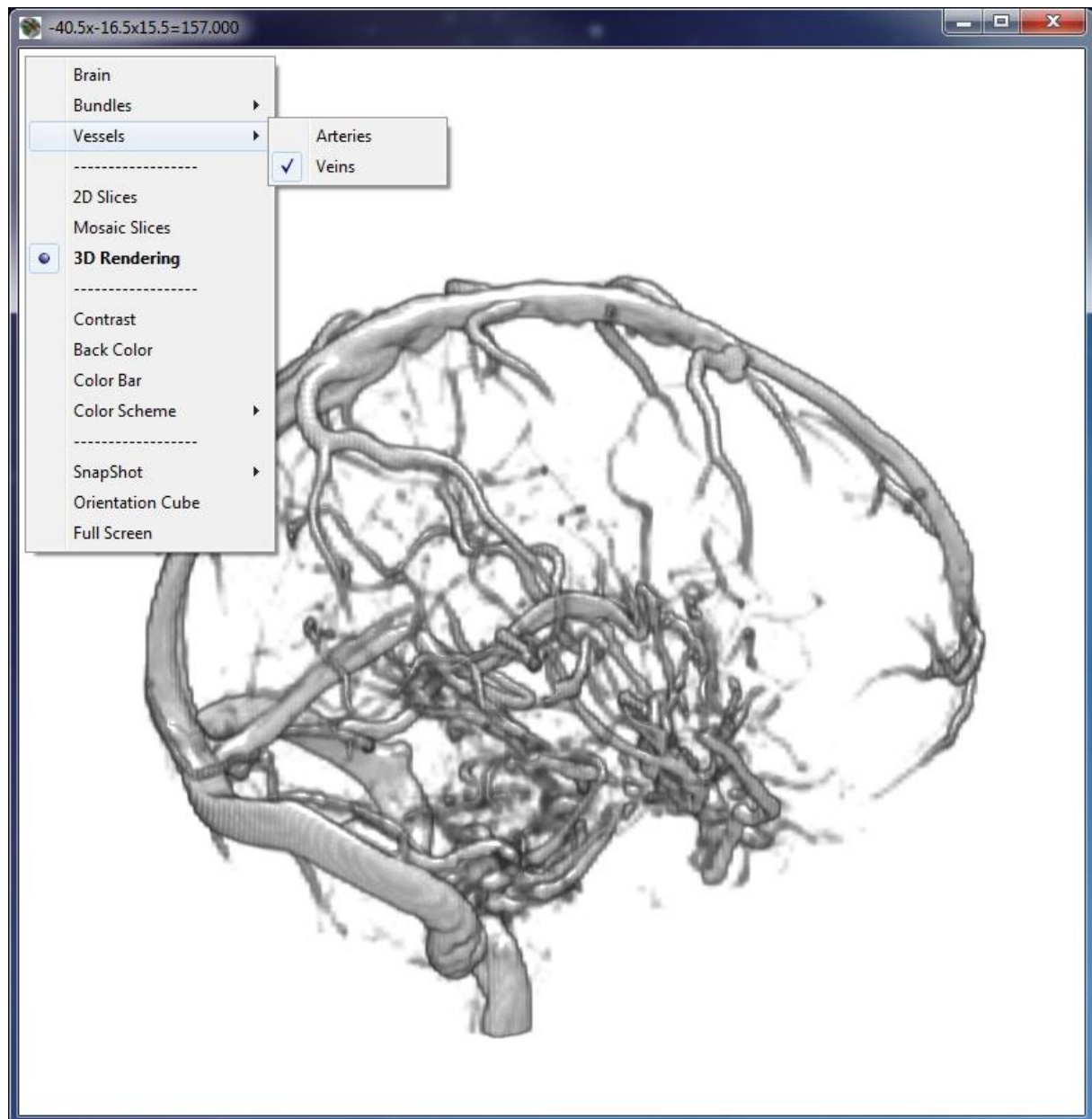


At last, combine this artery with the Right Superior Longitudinal Fasciculus by LC on the matching empty square in the **White Matter Tab Selector** and display these selected items using the “Brain Ghost” sub-menu of the “Bundles” 3D VR Template (by RC on the 3D rendering area):

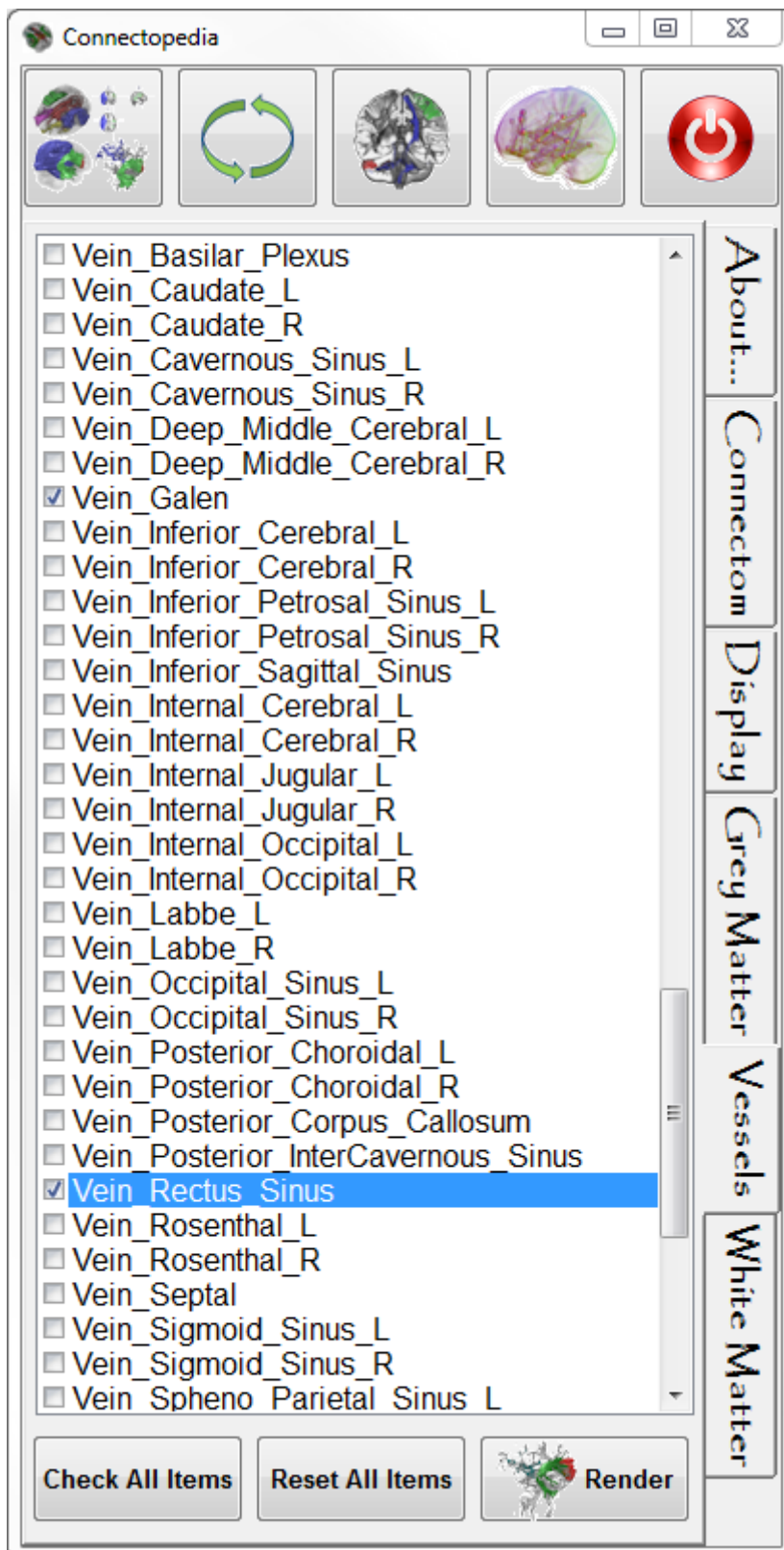


VI. Third exercise: Grey Matter Structures and Veins

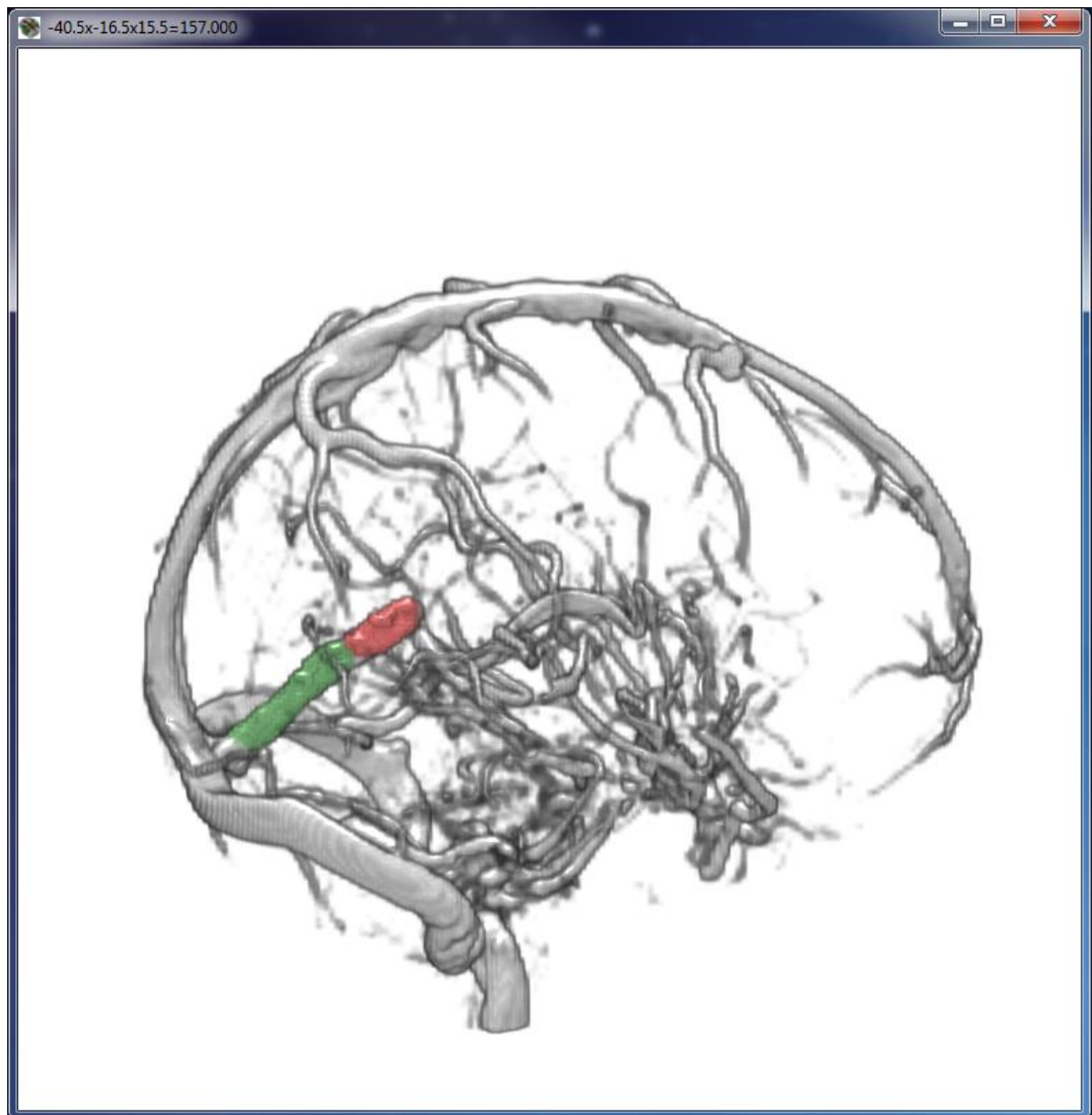
User can also reconstruct brain veins and venous sinuses using the “Veins” Template of the 3D rendering window:



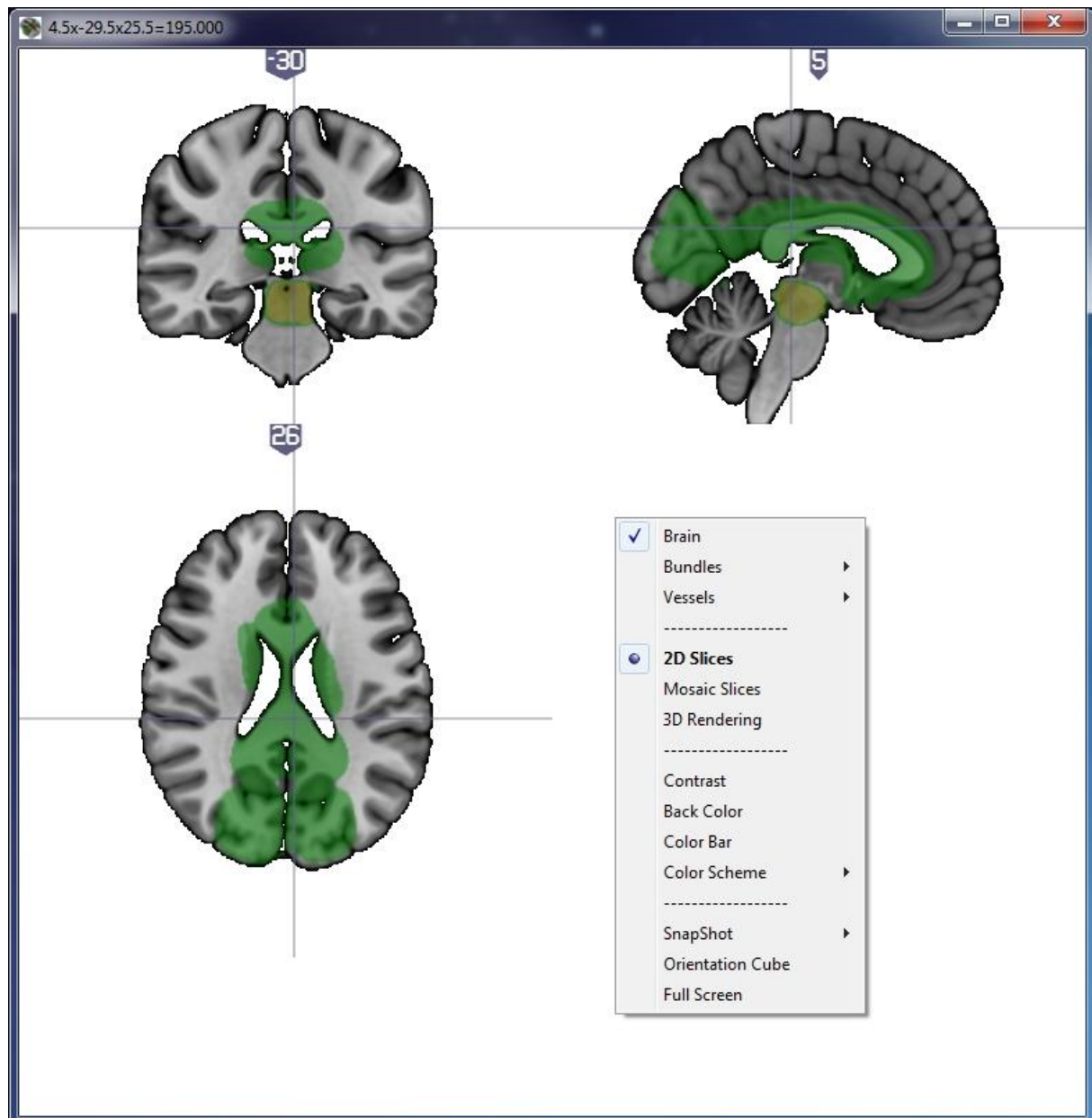
Let's now study the both Thalami combined with the Galen Vein and the Straight Sinus (e.g. in case of deep venous thrombosis).



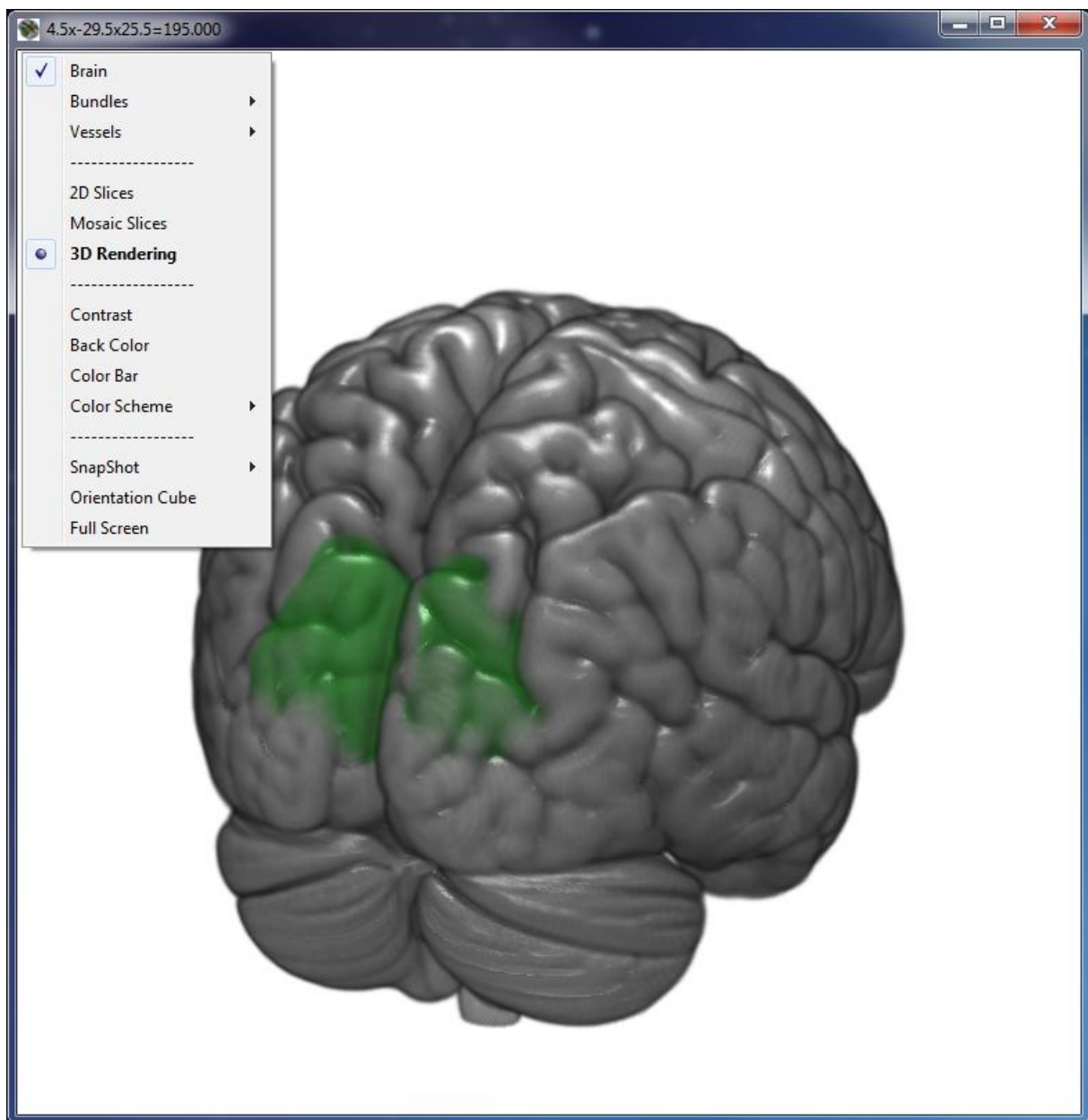
First select in the **Vessels Tab** **Selector** the matching venous structures (« Vein_Galen » and « Vein_Rectus_Sinus ») by LC on the small empty square (to deselect it, just LC again), then set the “Veins” Template using RC on the 3D rendering area, then press the Render Button.



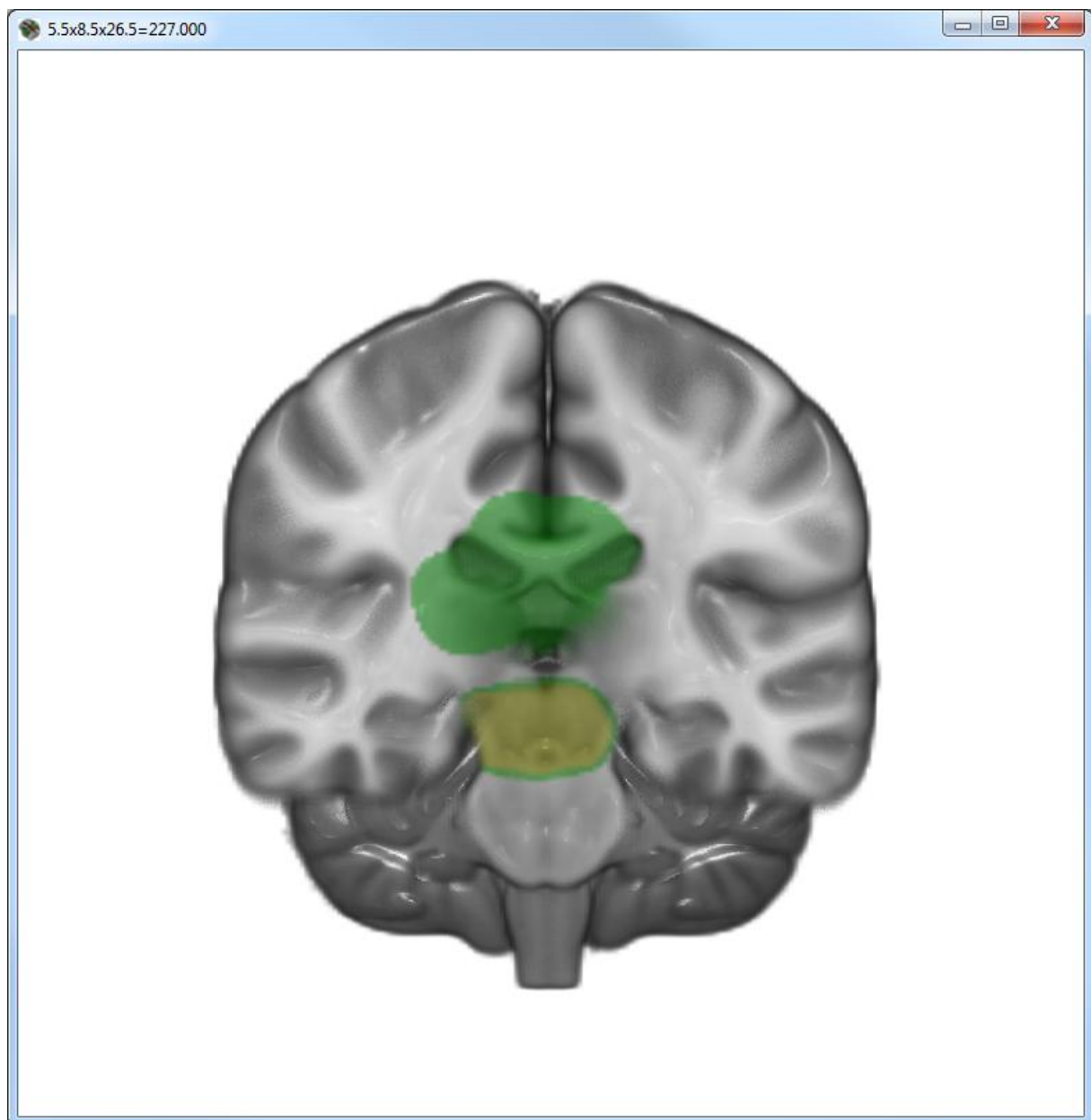
Now let's see how are these venous territories in 2D (RC on the 3D Rendering area, and select the « Brain » Template, then the « 2D Slices »):

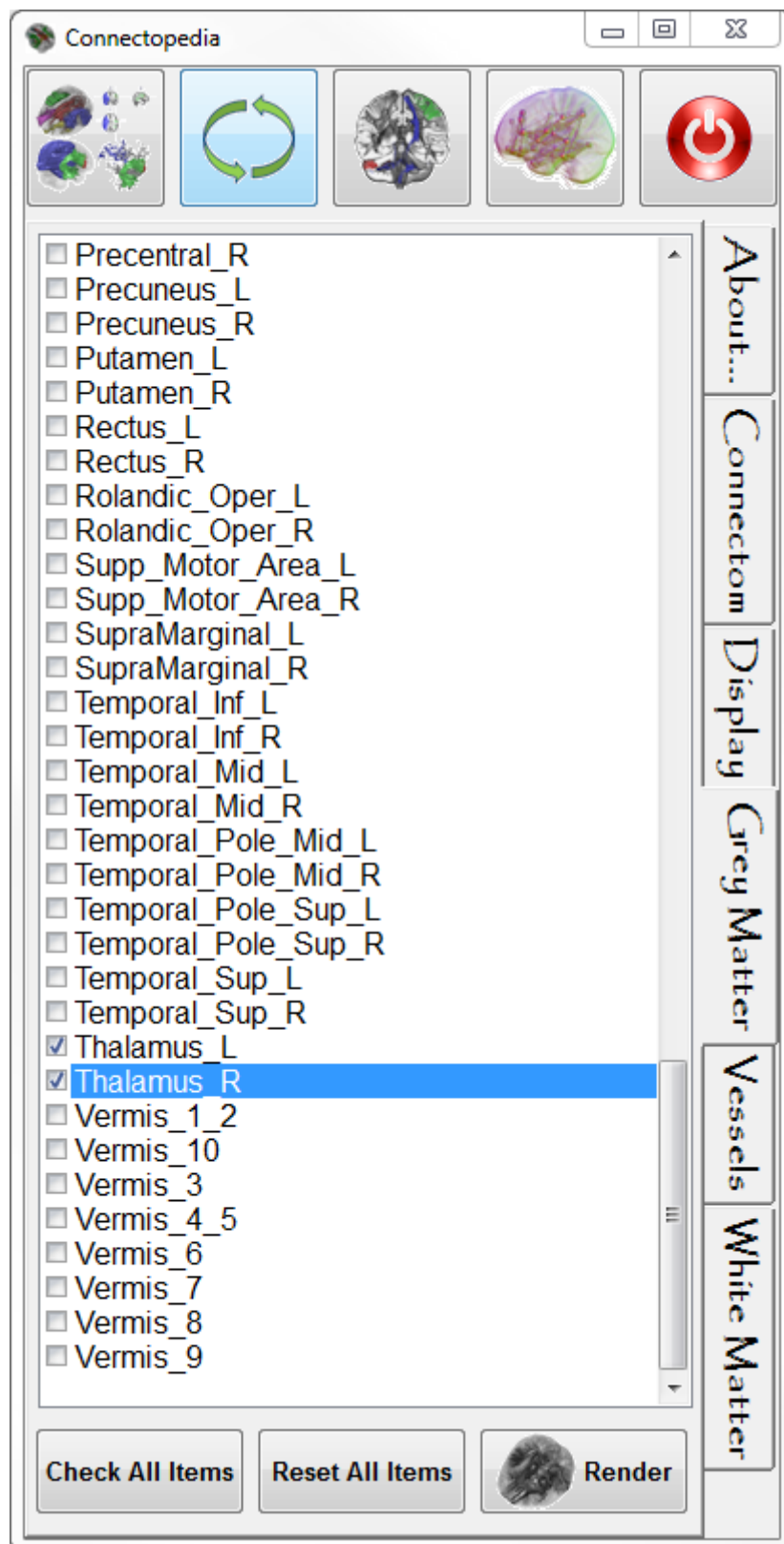


Let's see them in 3D (RC on the 3D Rendering area and select « 3D Rendering »):

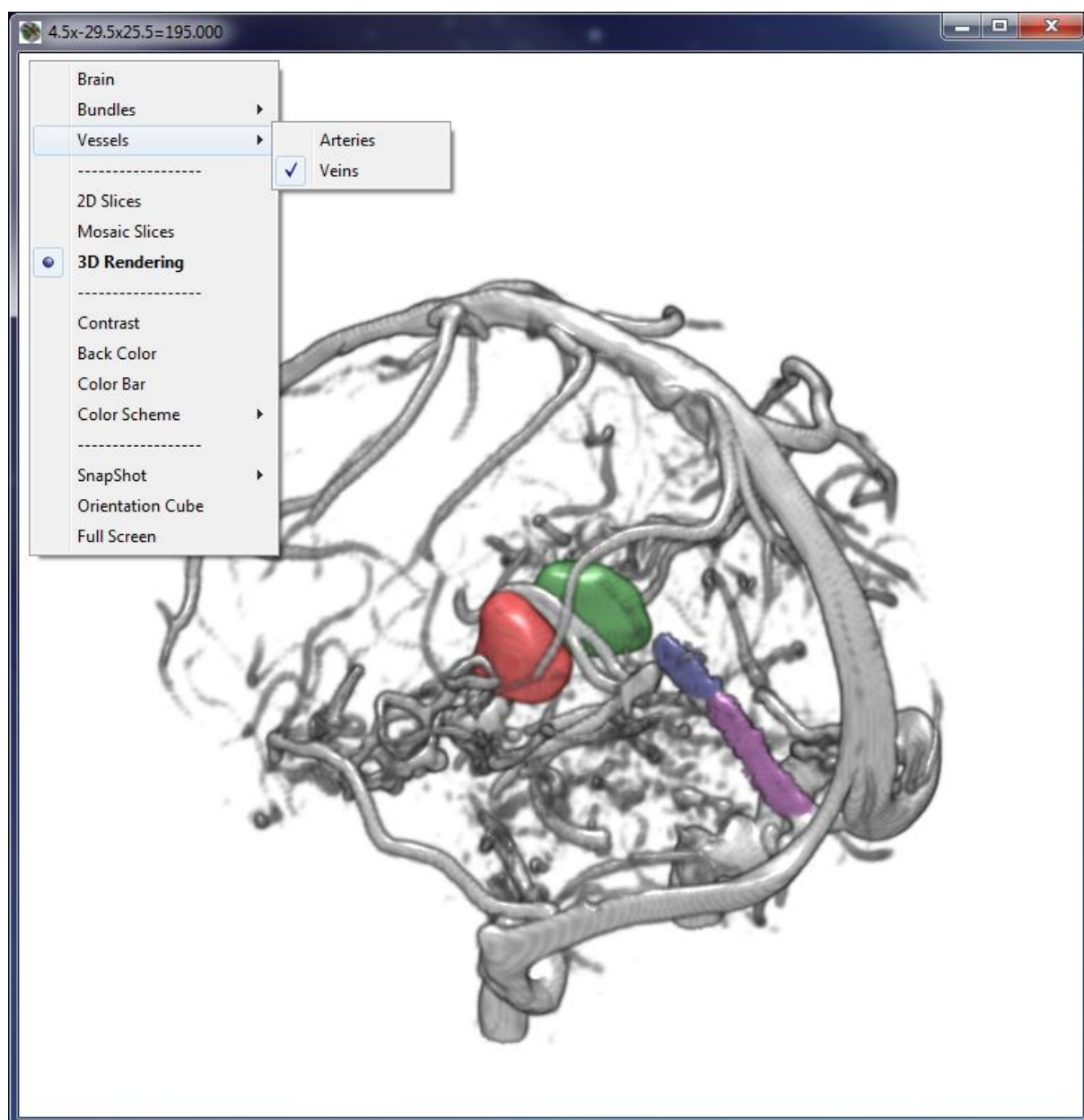


And inside the brain when applying the **3D Cut** Clipping Tool:

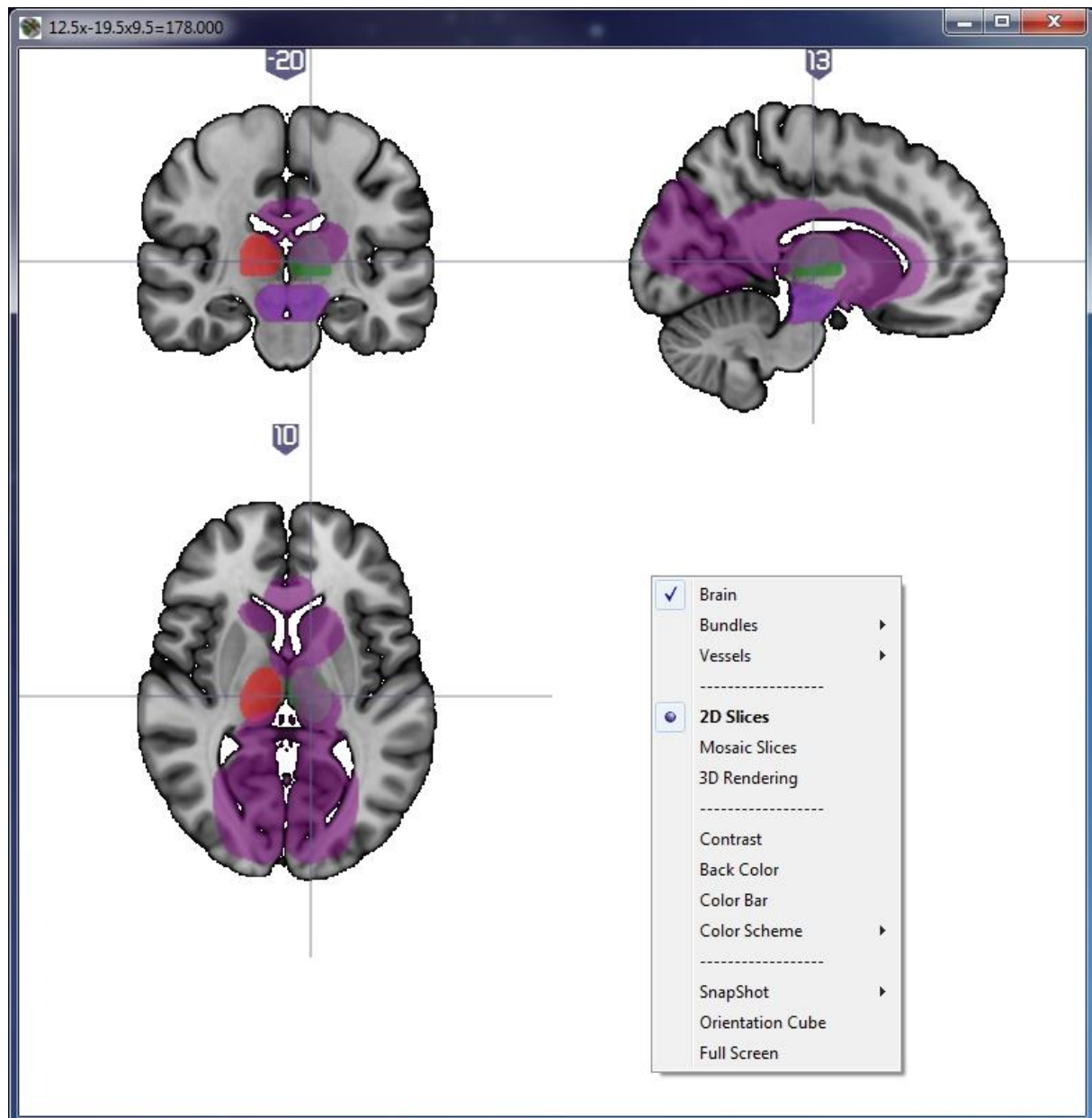




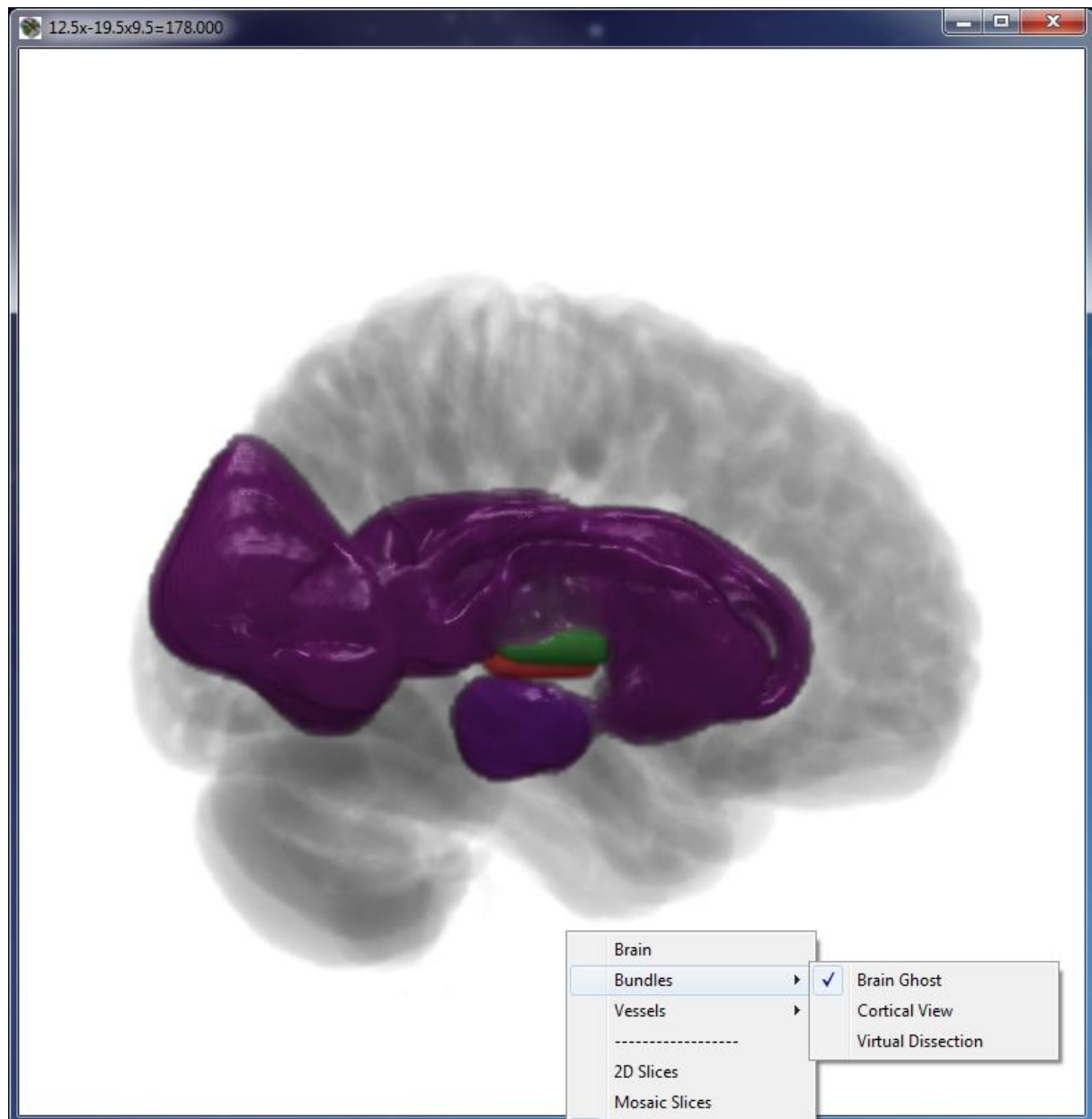
Now select the « Thalamus_R » and « Thalamus_L » by LC on the empty square in the Gery Matter Tab Selector, and RC on the 3D Rendering area to select the « Veins » Template again, showing venous and grey matter structures, then press the Render Button:



Let's see how these structures are each other intermingled in « 2D Slices » by RC on the 3D Rendering area and selecting the Brain Template:



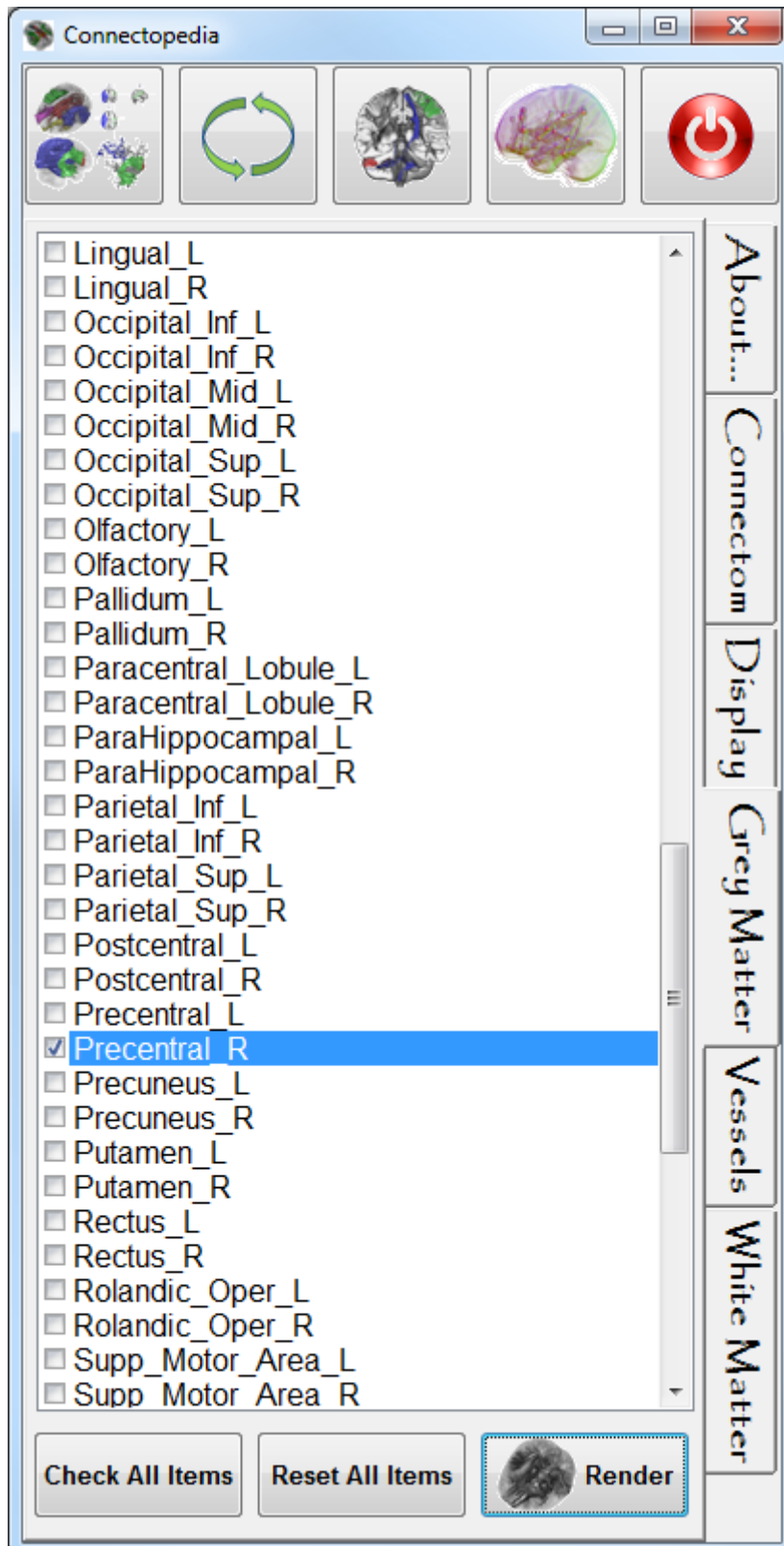
Now have a look at the 3D VR reconstruction of these structures by RC on the 3D Rendering area and selecting the “Brain Ghost” sub-menu of the “Bundles” Template:



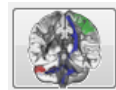
Venous drainages are overlapping the both Thalami, as you can see.

VII. Fourth exercise: Tracking fiber pathways between two cortical areas

Connectopedia includes an algorithm involved in automated identification of linked grey matter structures by white matter fiber bundles.

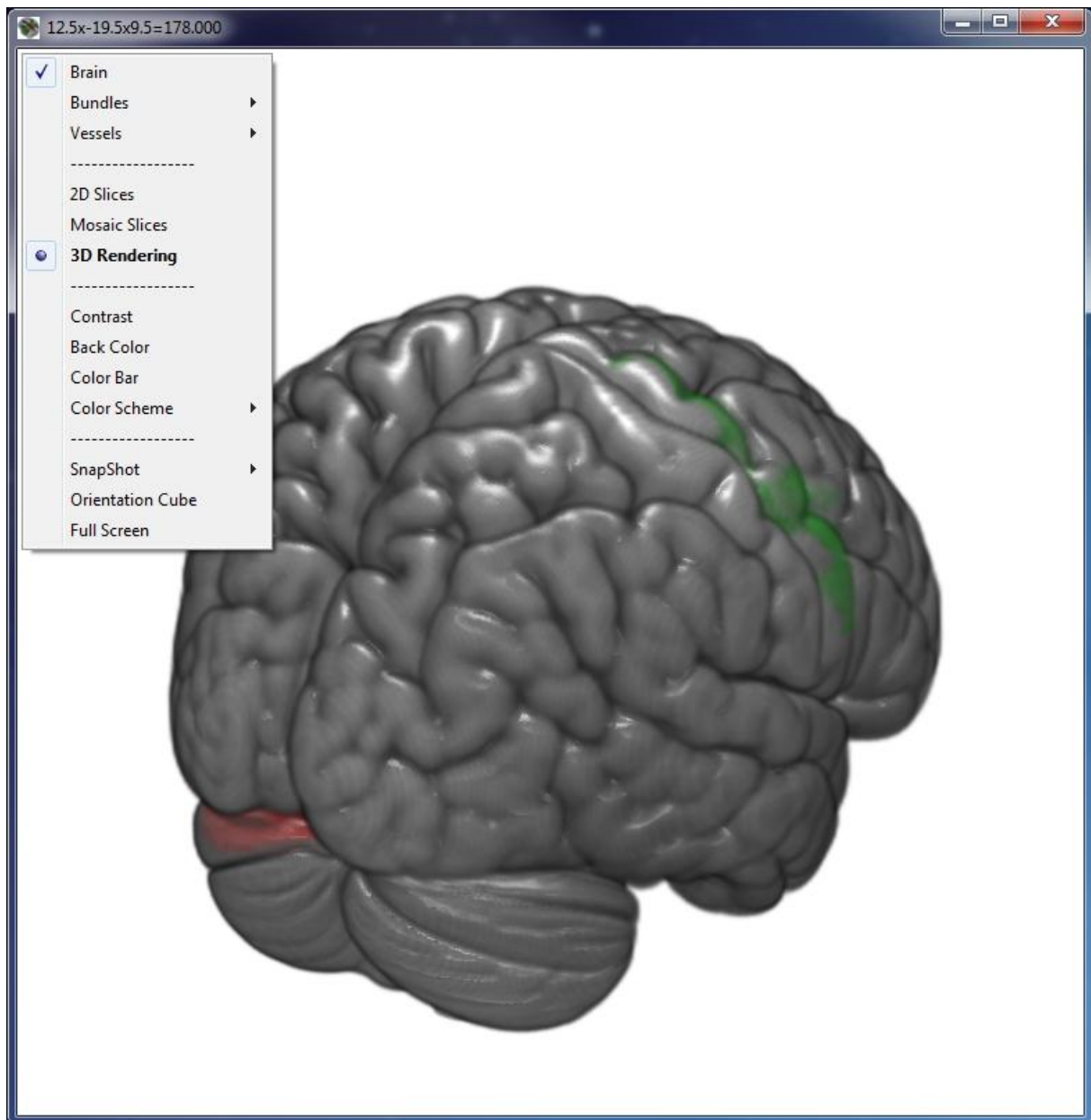


User can check the relations existing between grey matter areas using the “Tracking



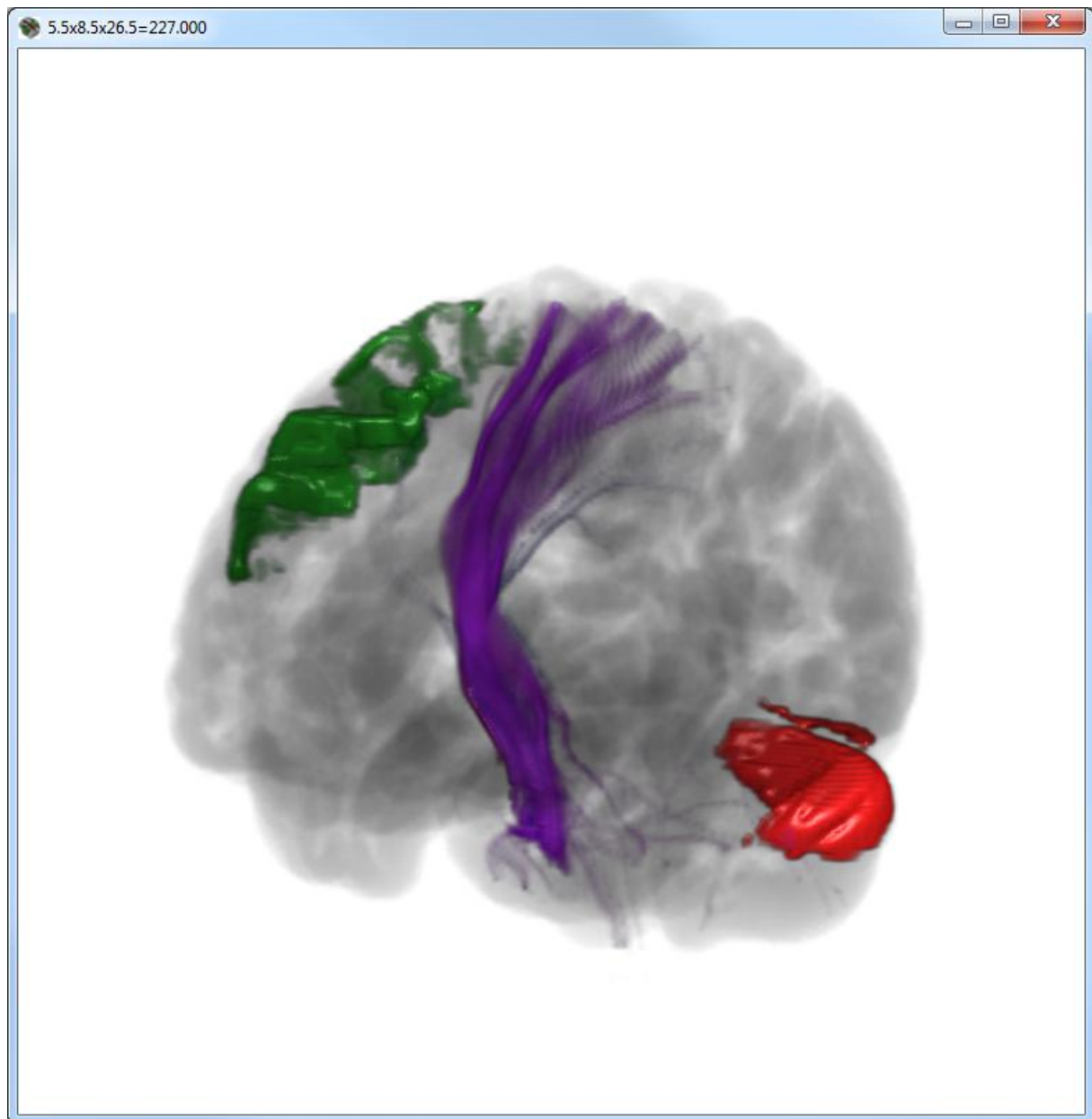
Pathways” Button in the **Selector** window.

Let’s see which fibers bundle(s) is (are) linking the Right Pre-Central cortical area and the Left Cerebellum Crus 1. First select the cortical areas by LC on the empty square in the Grey Matter Tab Selector, then press the Render button.



Then LC on the “Track Pathways” Button :

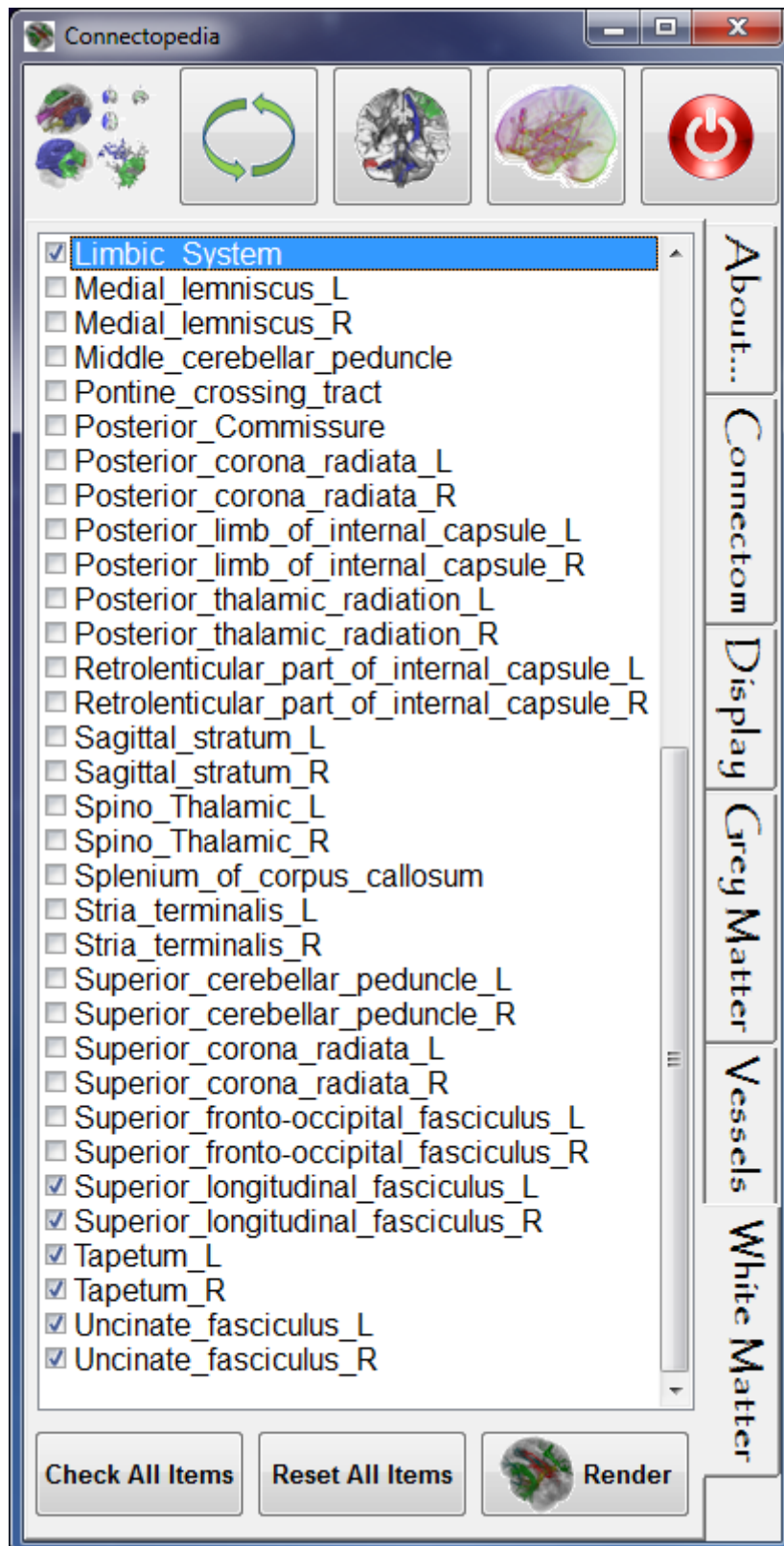
Connectopedia will detect the fiber bundles that are linking these two areas, here the “Cerebral_Peduncle_R” and the “Posterior_Limb_Internal_Capsule_R” by the cortico-ponto-cerebellar tract, and will display the found bundle(s) in the “Brain Ghost” sub-menu of the “Bundles” Template 3D VR mode :



User can select from 2 to 116 cortical areas, but the more you select, the less you have chance to detect common bundles (inclusive arithmetics).

VIII. Fifth exercise: Virtual Dissection with “Anatomist” Drawings Rendering

Connectopedia includes a tool to perform virtual dissection in the “19th century anatomists” drawings fashion, either in color or black and white.

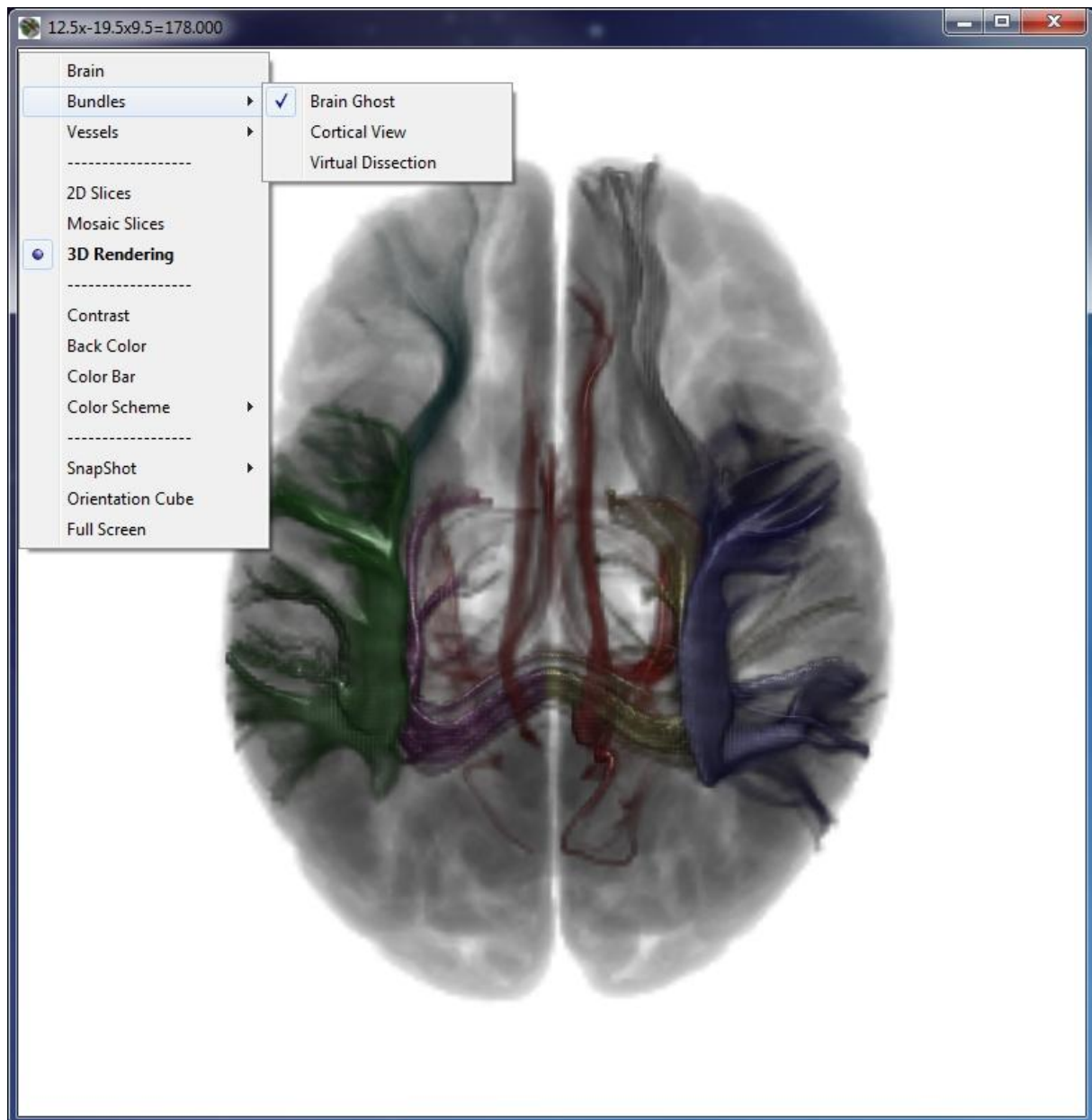


Let's start using the following White Matter Tracts, selected in the **White Matter Selector Tab** by LC on the empty square:

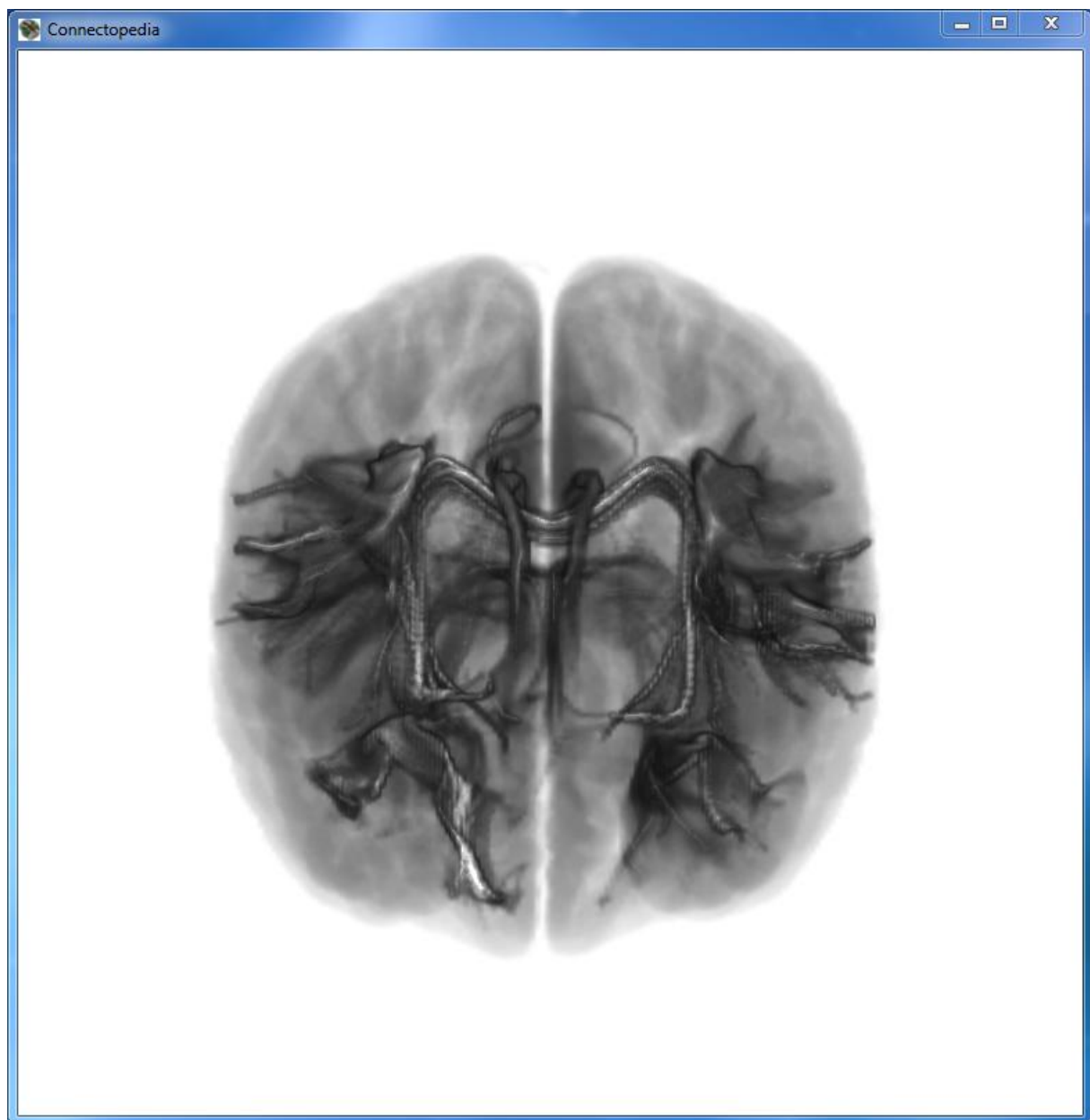
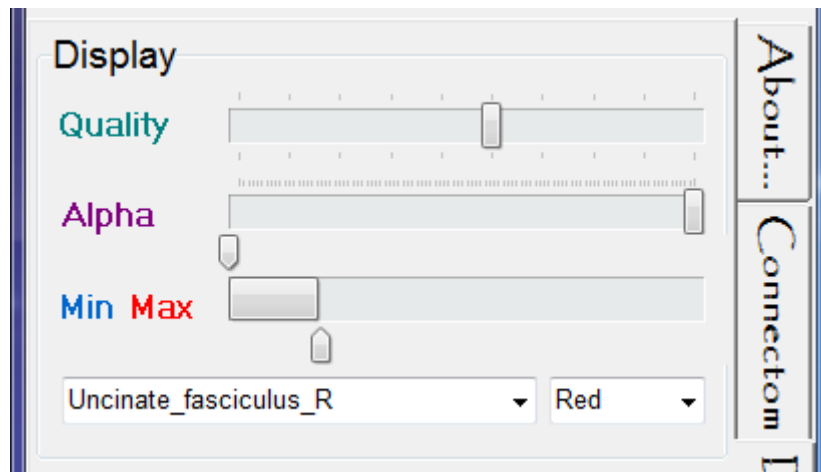
- Limbic System
 - Superior Longitudinal Fasciculus R
 - Superior Longitudinal Fasciculus L
 - Tapetum R
 - Tapetum L
 - Uncinate Fasciculus R
 - Uncinate Fasciculus L

Set the 3D Render window property to “Brain Ghost” sub-menu of the “Bundles” menu Template, and press the Render button.

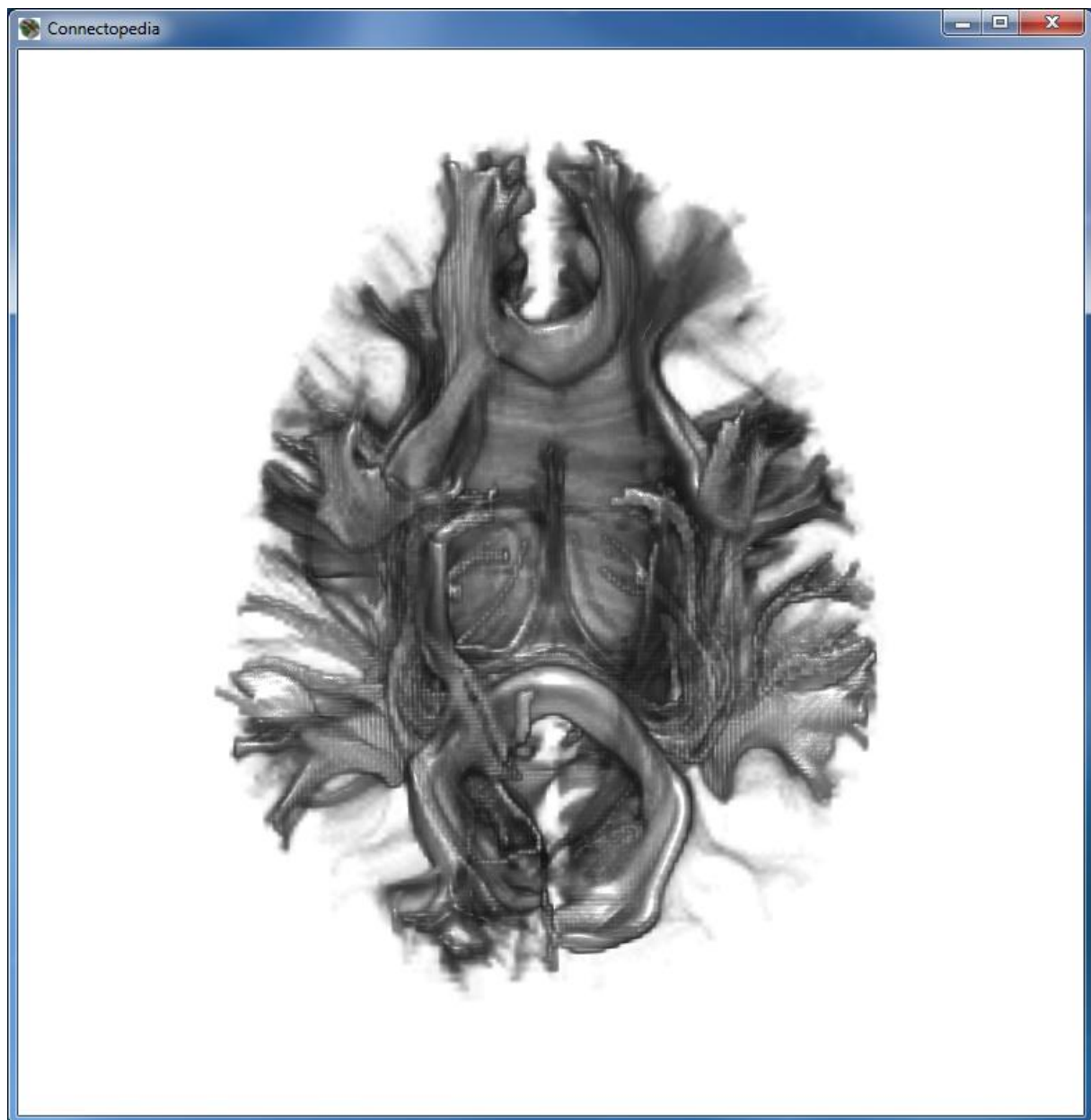
to see which fibers bundle(s) is (are) linking the Right Pre-Central cortical area and the Left Cerebellum Crus 1. First select the cortical areas by LC on the empty square in the **Grey Matter Tab** Selector, then press the Render button.



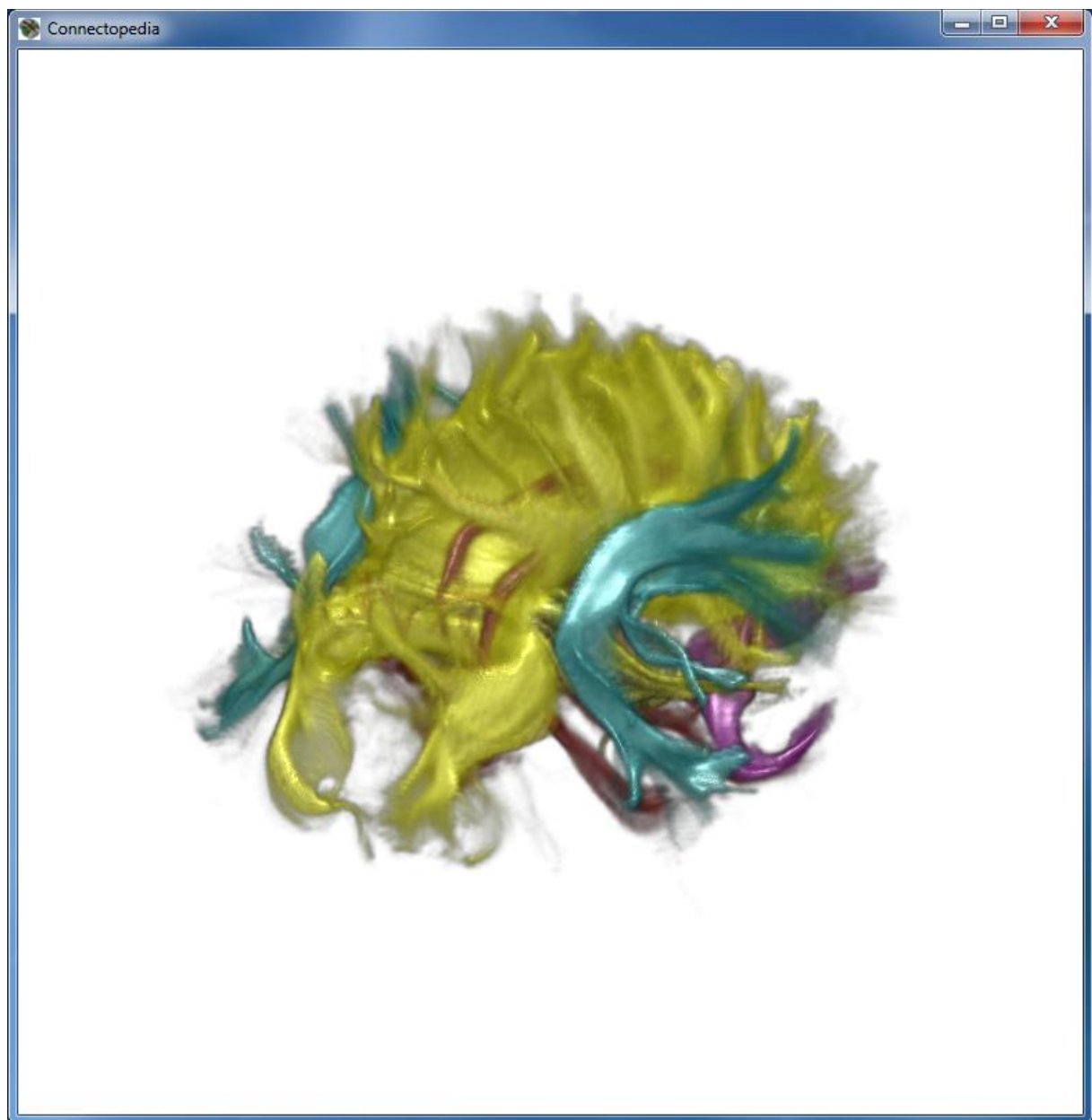
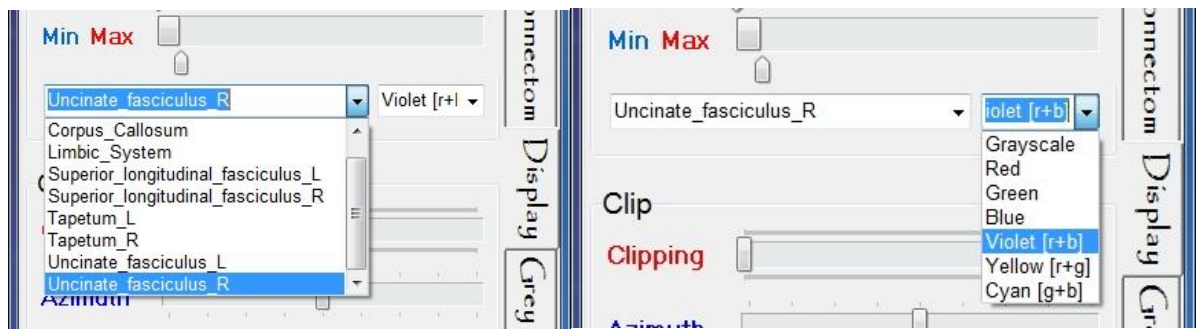
In the **Display Tab** of the **Selector**, set the “Alpha” property to 100 to render the selected bundles in Black and White.



Then select the “Virtual Dissection” sub-menu of the “Bundles” menu Template in the **3D Render** window to see the selected items without the outside brain. After the rendering, add the “Corpus Callosum” item by LC on the empty square in the **White Matter Tab** Selector, press the Render button, and set the “MinMax” property in the Display to to have a good quality rendering:



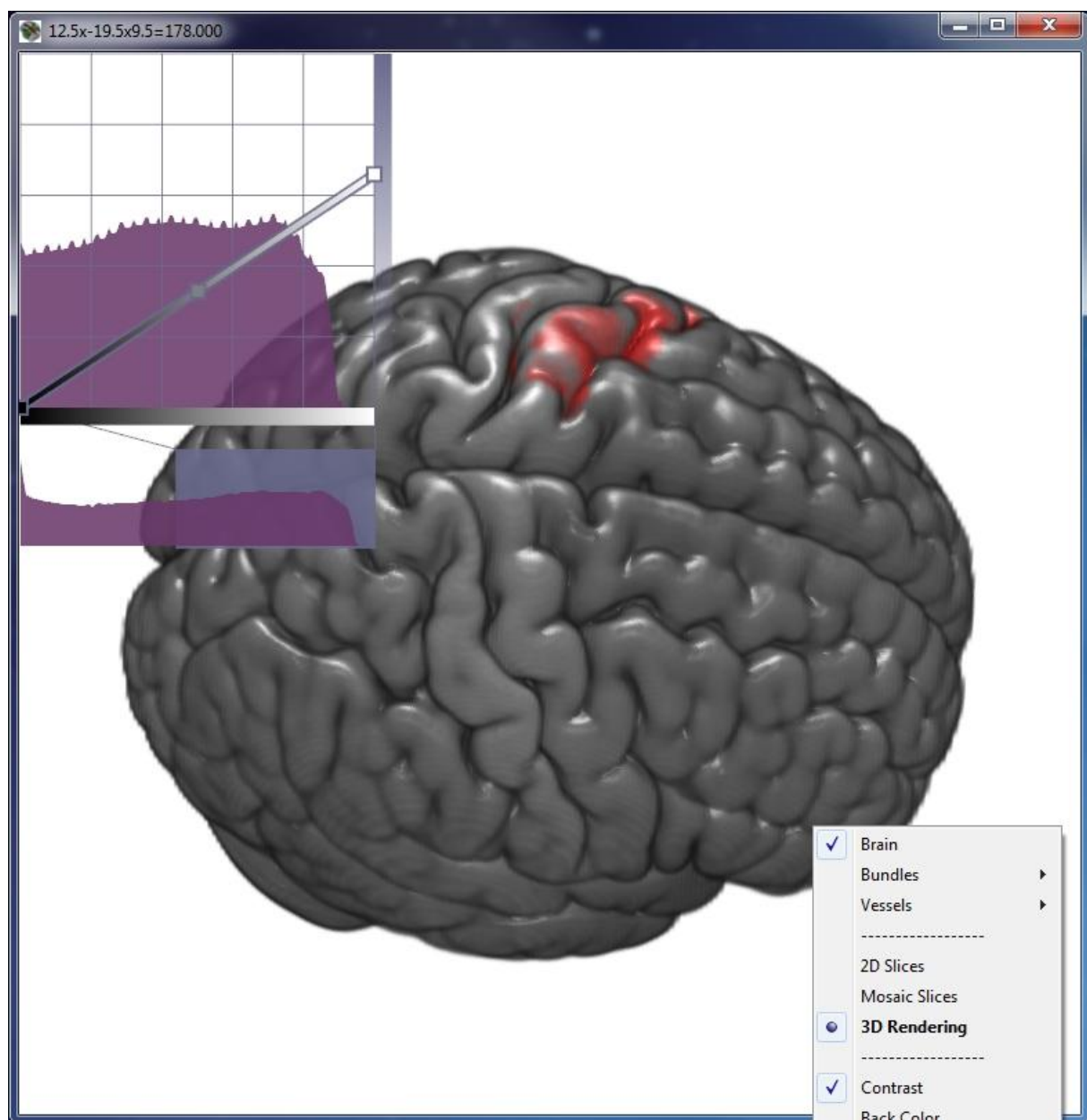
Set the “Alpha” property of the **Display Tab** to 50, and change the rendered color by selecting the reconstructed item and choosing the appropriate color:



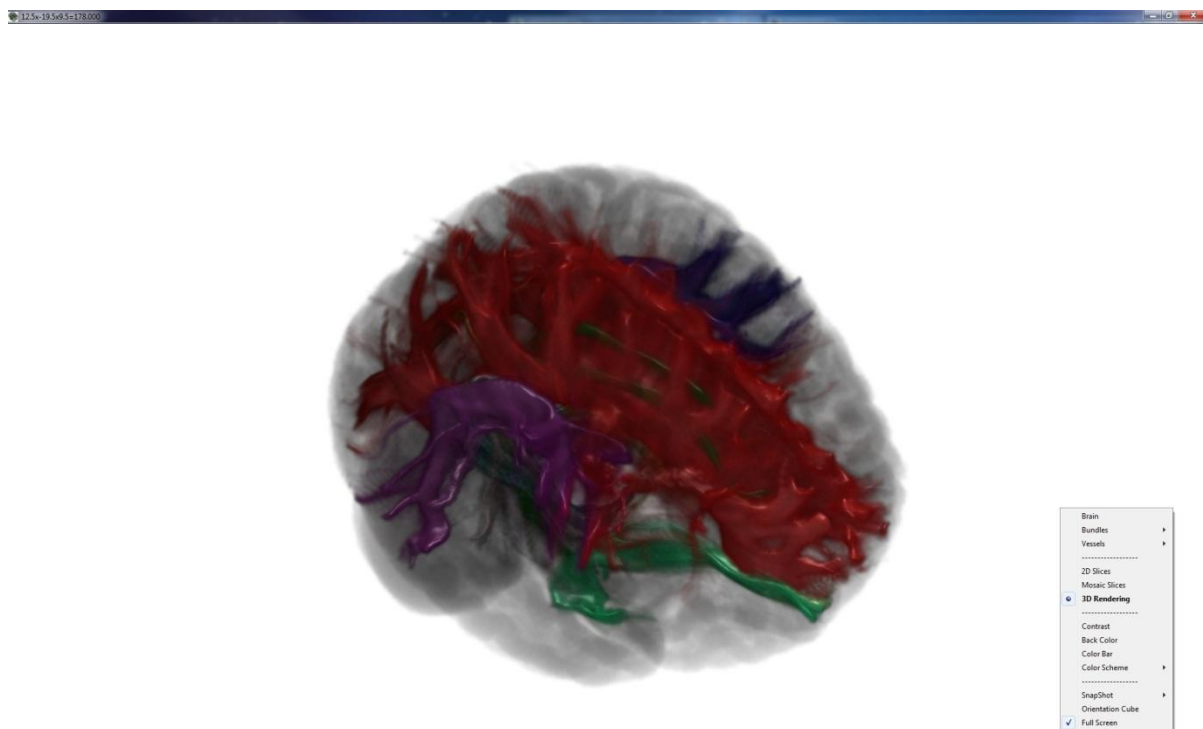
IX. Other functions :

By LC on the 3D rendering area, user can:

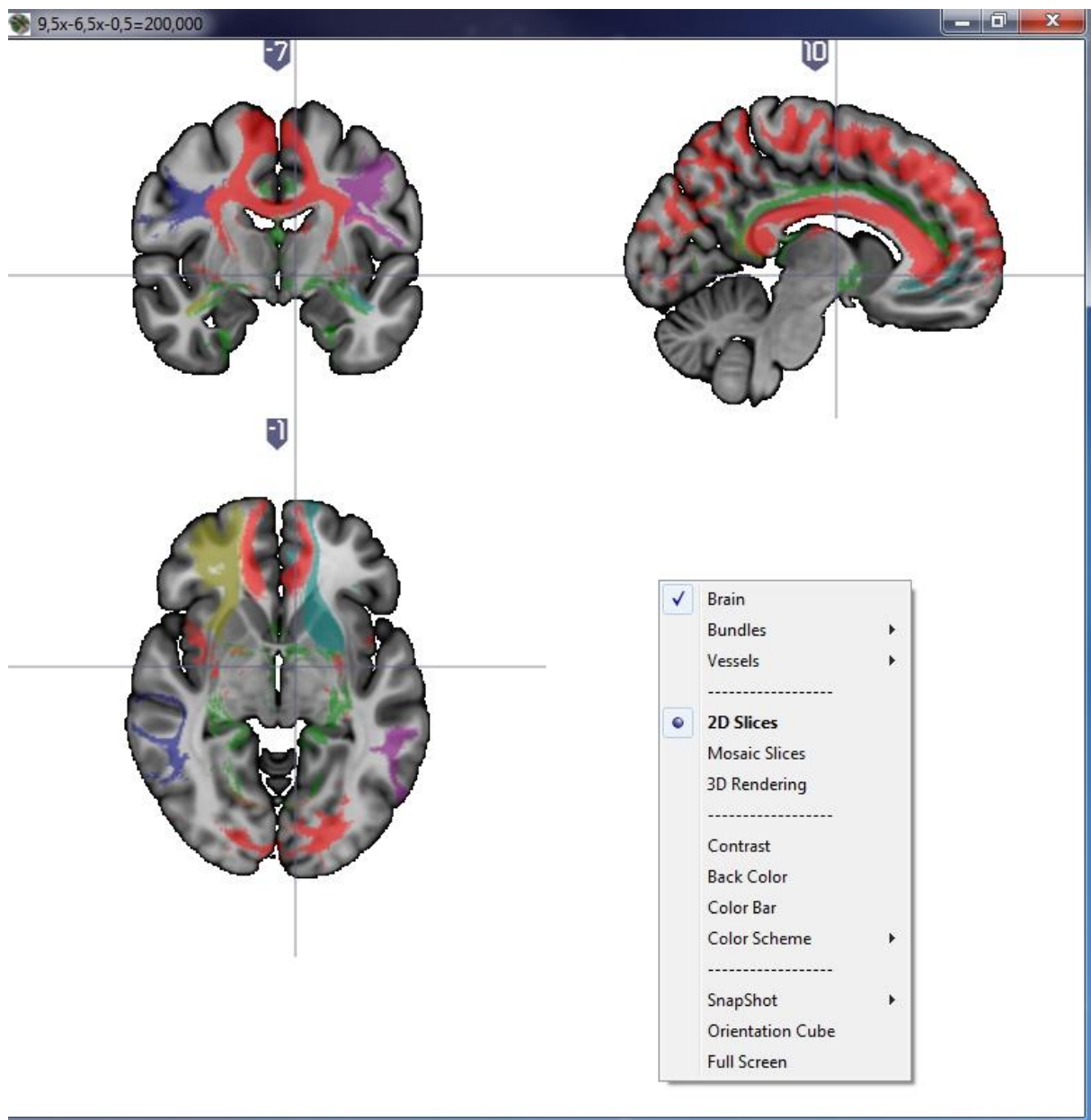
- Set Contrast (by LC on it)
- Set Back Color (here white)
- Set Color Bar visible
- Orientation Cube visible
- Take a snapshot of the 3D Rendering area



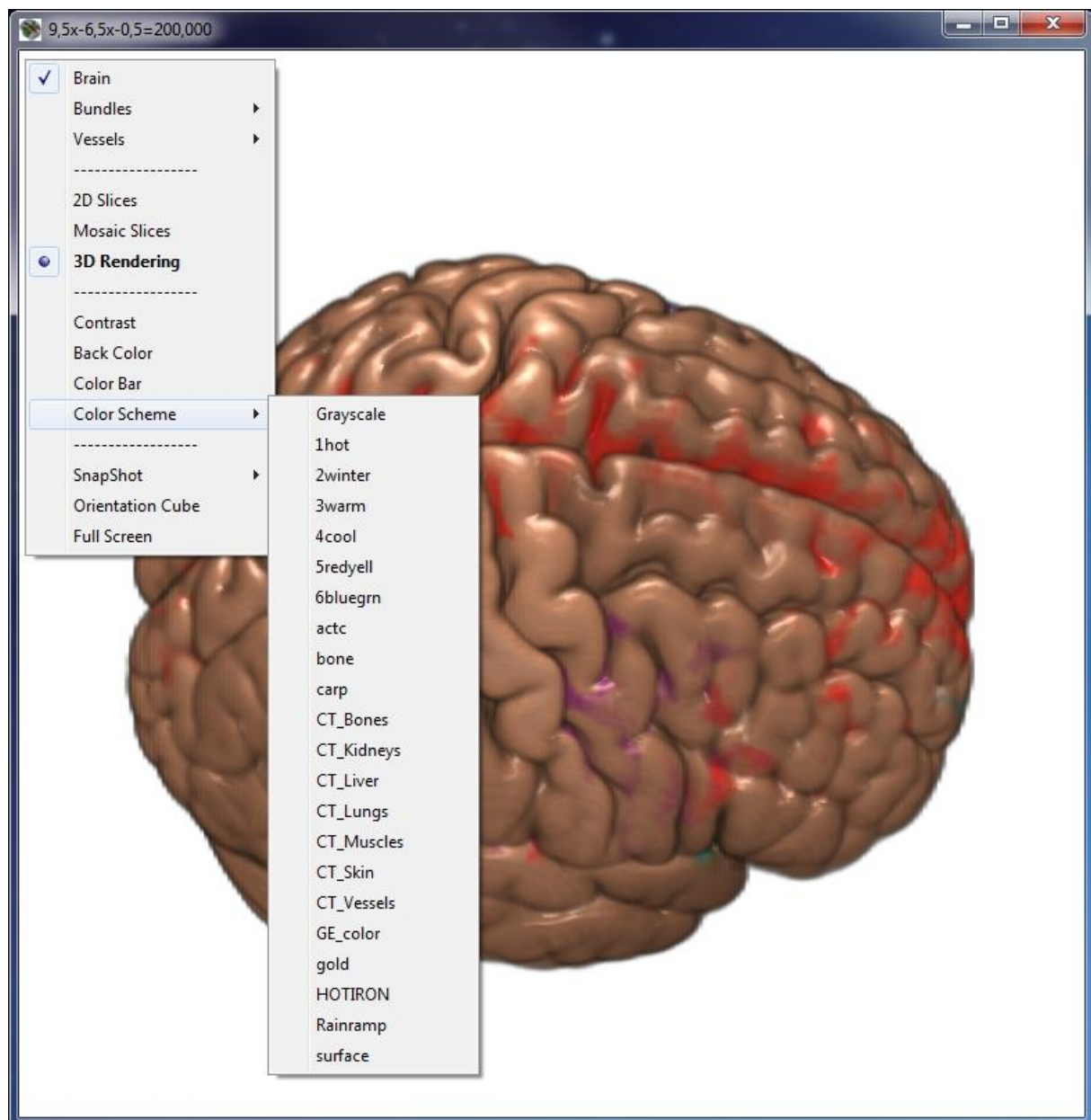
User can view 3D Rendering area in « Full Screen »:



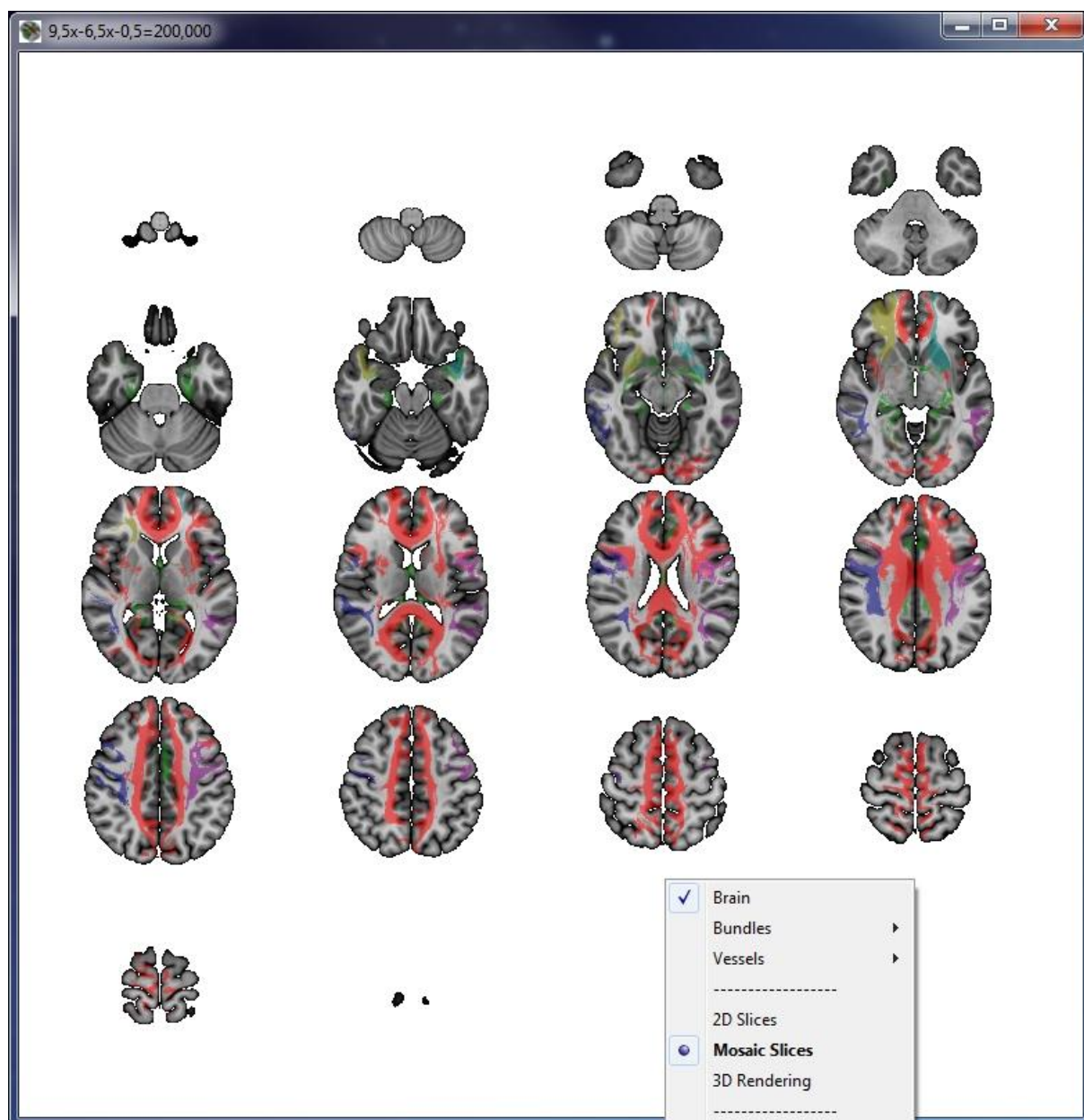
User can view in 2D MPR slices the selected items (WM, GM, and Vasculature):

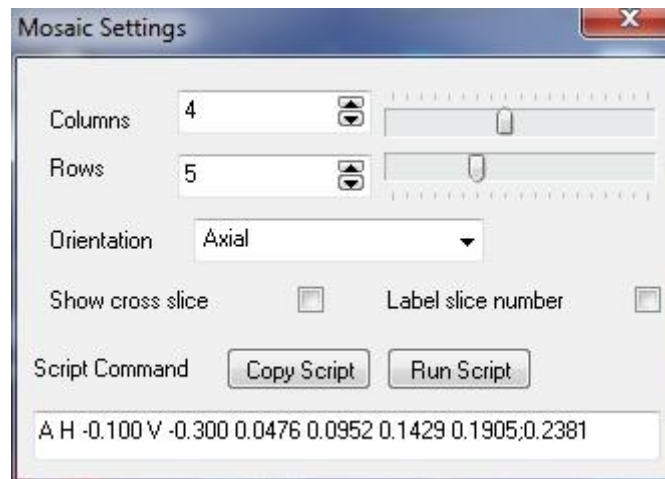


User can set the 3D Rendering color reconstruction set by LC on « Color Scheme »:



User can view mosaic slices of the selected Bundles / Areas / Vessels by LC on « Mosaic Slices »:





User can select axial, sagittal, coronal reconstructions, and the number / pattern of the displayed slices.

X. Troubleshooting's

User might have some problems in installing or running Connectopedia. Here are some clues.

IX.I Connectopedia Windows Version:

IX.I.I Installation Shortcut

After install, the link created in the “Start Program” menu of Windows might be erroneous.

Explore the files using “Windows Explorer” to see where Connectopedia have been installed (by default, “C:\DPTools\bin\Connectopedia”), then locate the “Connectopedia.exe” file. Create a symbolic link to the Desktop by Right-Click on it, then select “Send to...”, then “Desktop (Create Shortcut)”.

You should be able now to run Connectopedia by Double-Clicking on the link created on the Desktop.

IX.I.II Running issues

When Shortcut are erroneous, running Connectopedia can generate error messages at launch time, and Connectopedia can not be used.

Correcting the Connectopedia Shortcut (see section IX.I.I) generally solves this issue.

IX.II Connectopedia OSX Version:

Main issue with the OSX version is related to Mavericks GateKeeper, because Connectopedia is not signed as “Apple Approved” software yet.

Let's see how to overcome this issue (here “Onyx” software taken for example).

Starting with OS X Mountain Lion, Apple introduced a data execution prevention routine called Gatekeeper, which will block the automatic execution of programs that are either unsigned by an Apple Developer, or not issued through the App Store.

This routine prevents potentially malicious programs from running and harming the system or your data. However, while beneficial, it can also prevent legitimate programs from running, where it issues a warning that the program is not signed and will not allow it to run.



Warnings such as this will show when you attempt to open apps that are not signed, if you have Gatekeeper enabled on your Mac.

If you regularly use third-party programs that give this warning, then one option is to turn off Gatekeeper in the Security System Preferences, but this will prevent the service from helping secure your **Mac**.

To overcome this, there are two options. The first is to right-click the program and use the "Open" contextual menu item to initially launch such programs. The use of this menu suggests you explicitly intend to open the program, instead of perhaps inadvertently launching it with a double-click. When you do this, a warning message will still appear; however, if you choose the option to open the program, then a Gatekeeper exception will be made for it.



This message and button will appear in the Security & Privacy system preferences when you encounter an unsigned program.

If you have installed **OS X Mavericks** on your system, Apple has introduced another means for bypassing Gatekeeper. If you open a program that issues a Gatekeeper warning, then even if you have dismissed the warning, you can go to the Security pane of System Preferences, where you will see a message under the Gatekeeper settings about the recently blocked program. Next to this message is a button titled "Open Anyway," which if clicked, will launch the program and make an exception for it in the Gatekeeper database.

Even though the extra steps to use this new feature make it less convenient than using the contextual menu, it is still a new option for those using OS X Mavericks.

IX.III OpenGL issues with Connectopedia Windows and OSX Version:

Both Windows and OSX versions of Connectopedia can be affected by a strange OpenGL issue due to the way OpenGL Shaders are rendered by the Video Card.

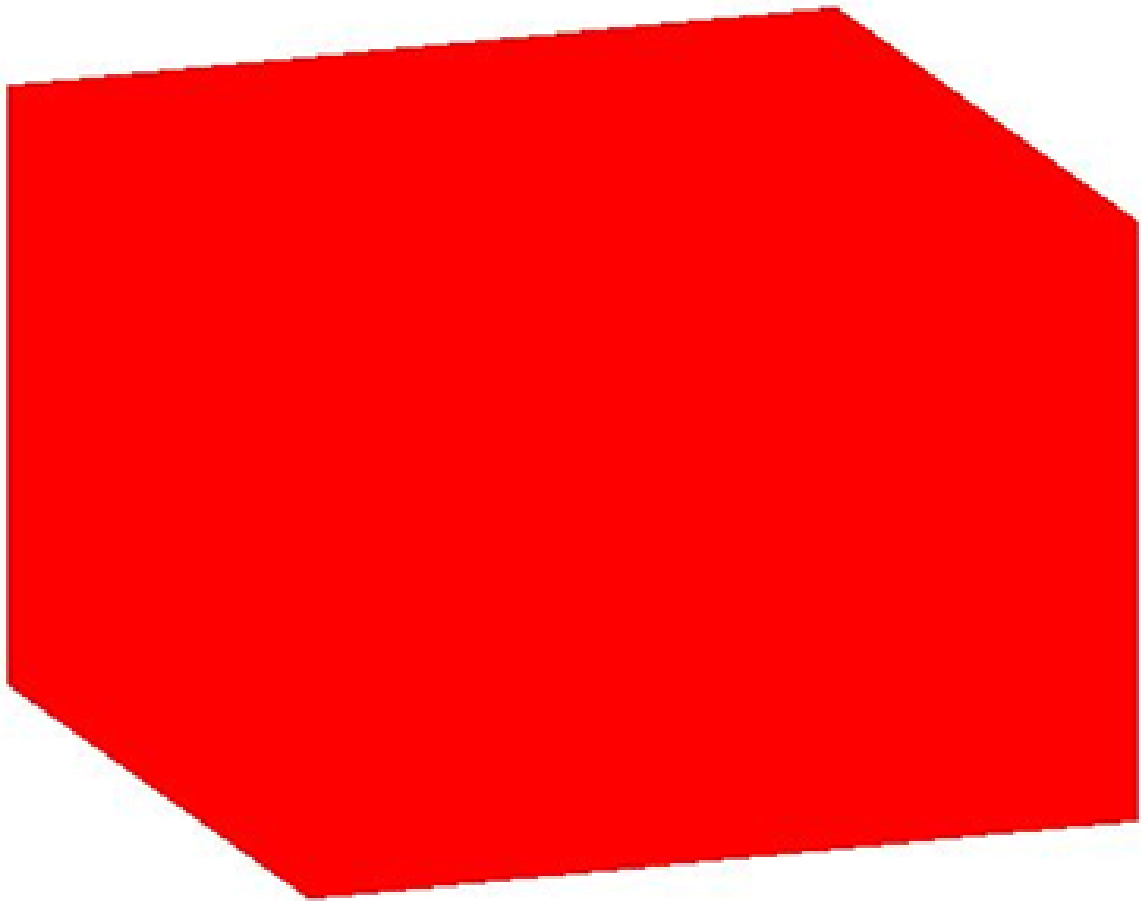
Brain can be rendered “deformed” such as:



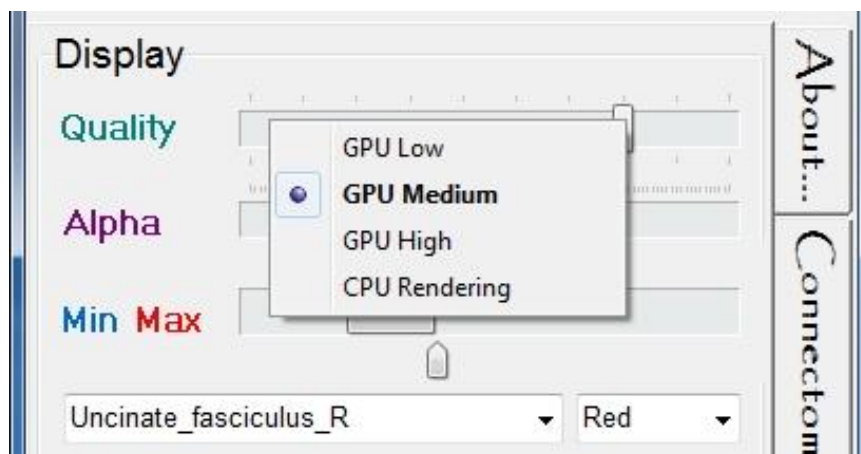
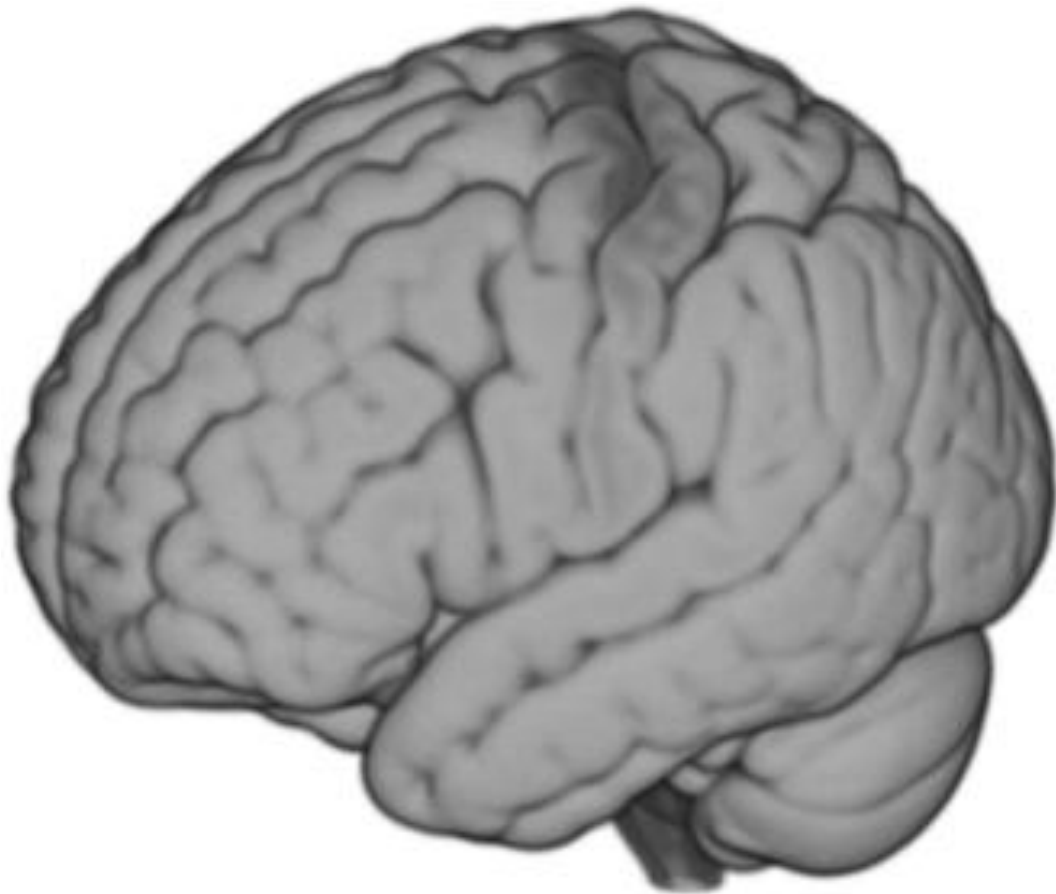
When user encounters this issue, closing then running Connectopedia again should correct this.



Other issues might also be encountered when the OpenGL drivers of the Video Card are incompletely implemented, e.g. when using VMWare Fusion on OSX for virtualization of the DPTools or Windows Standalone distribution of Connectopedia:



To overcome this issue, user can select different Rendering Quality, from “GPU Low” to “High Quality”, and “CPU Rendering” by Right-Clicking on “Shader Quality” in the **Display Panel**.



All these issues are not exhaustive. If you have any pitfall or comment, please send an email to: denis.ducieux@fmritools.org

Visit <http://www.fmritools.org> to see Teaching Files and Videos related to Connectopedia.

Enjoy !

