Surgical Planning Laboratory
Brigham and Women's Hospital
Boston, Massachusetts USA

a teaching affiliate of
Harvard Medical School

3D VISUALIZATION OF DICOM IMAGES FOR RADIOLOGICAL APPLICATIONS

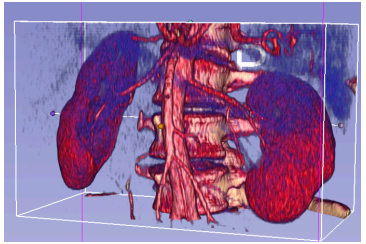
Sonia Pujol, PhD, Harvard Medical School
Surgical Planning Laboratory, Brigham and Women's Hospital

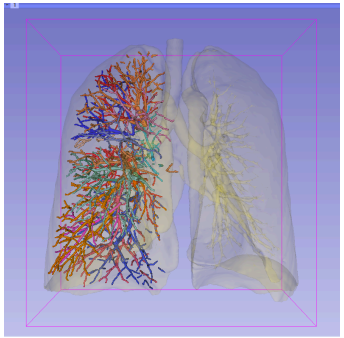
Kitt Shaffer, MD, PhD, Boston University
Vice-Chairman for Education, Boston University School of Medicine

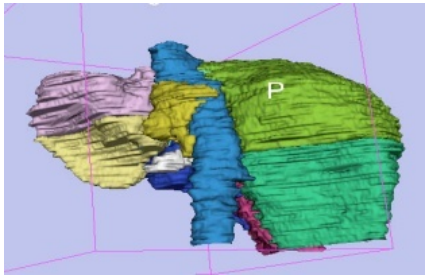
Ron Kikinis, MD, Harvard Medical School
Surgical Planning Laboratory, Brigham and Women's Hospital

3D Visualization of DICOM images for Radiological applications

Following this tutorial, you will be able to load and visualize DICOM volumes with 3D Slicer, and to interact in 3D with structural images and models of the anatomy.







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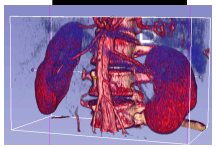
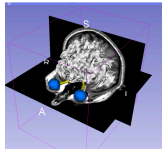
Overview

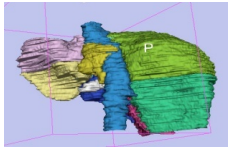
Part I: Introduction to the 3DSlicer software

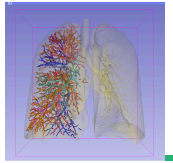




Part II: 3D Data Loading and visualization of DICOM images

- Volume Rendering of thoraco-abdominal CT data
- Surface Rendering of MR head data





Part III: 3D interactive exploration of the anatomy

- Exploration of the Segments of the liver
- Exploration of the Segments of the lung

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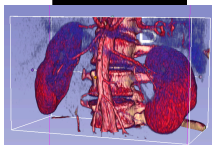

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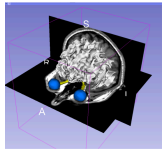

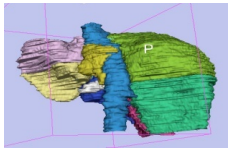

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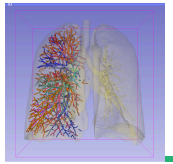

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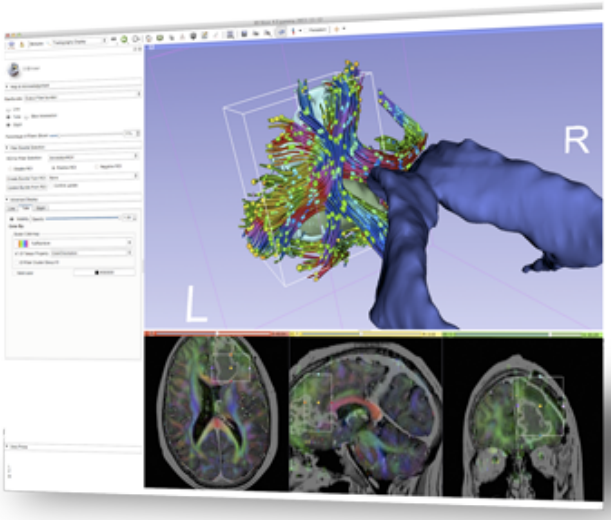
Introduction to the 3DSlicer software



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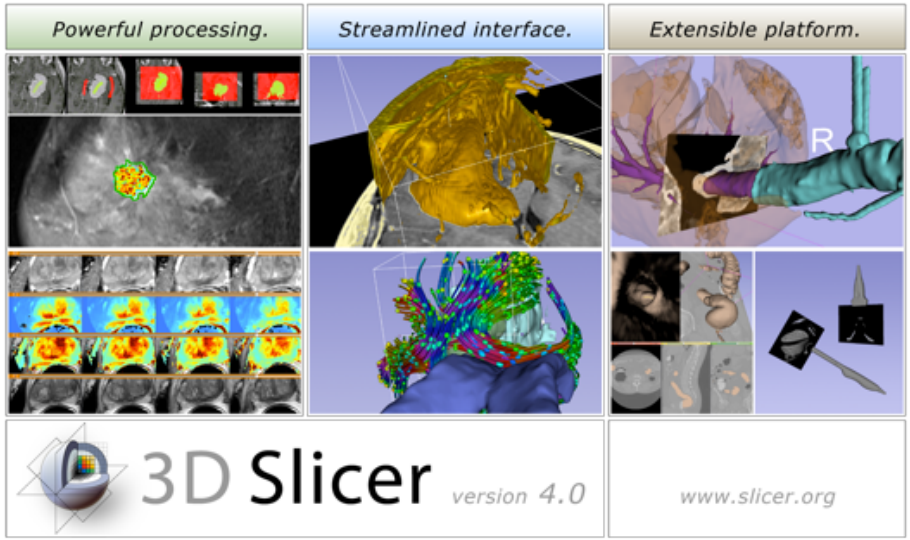
3DSlicer



3DSlicer is a freely available open-source platform for segmentation, registration and 3D visualization of medical imaging data.

3DSlicer is a multi-institutional effort supported by the National Institute of Health.

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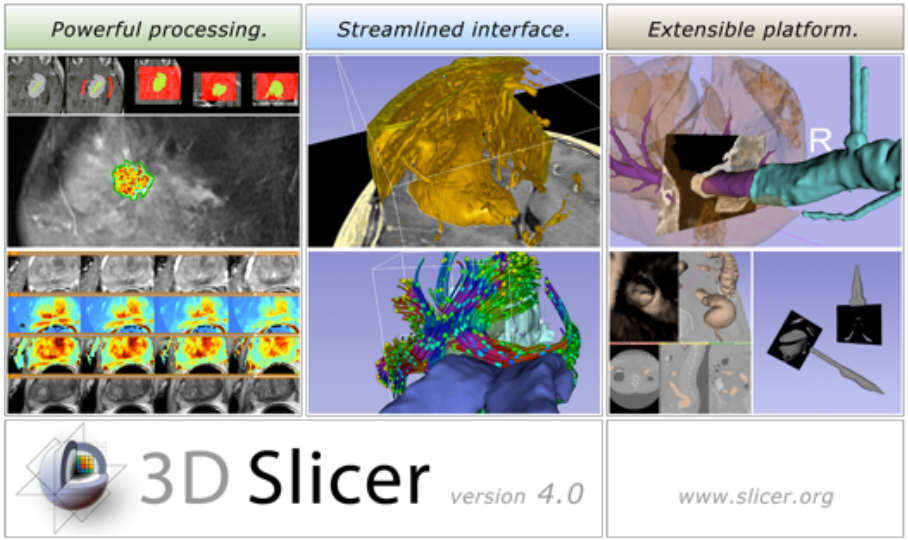
3DSlicer



- 3DSlicer version 4.3 is a multi-platform software running on Windows, Linux, and Mac OSX
- Slicer is distributed under a BSD license with no restriction on use
- Slicer is a tool for research, and is not FDA approved

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.

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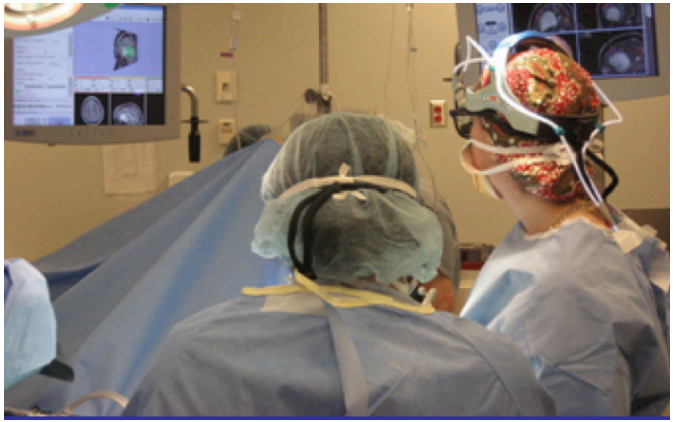
An interdisciplinary platform

An open-source environment for software developers



An end-user application for clinical investigators and scientists

A software platform that is both easy to use for clinical researchers and easy to extend for programmers

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3DSlicer History

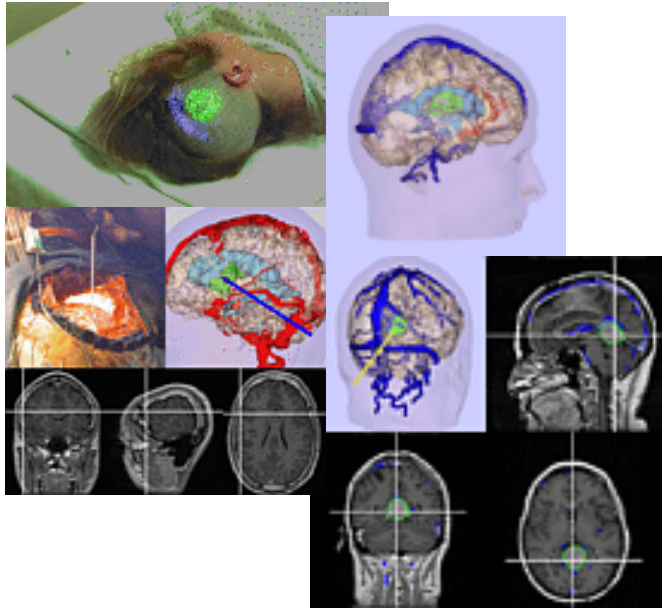

Image Courtesy of the CSAIL, MIT

- 1997: Slicer started as a research project between the Surgical Planning Lab (Harvard) and the CSAIL (MIT)

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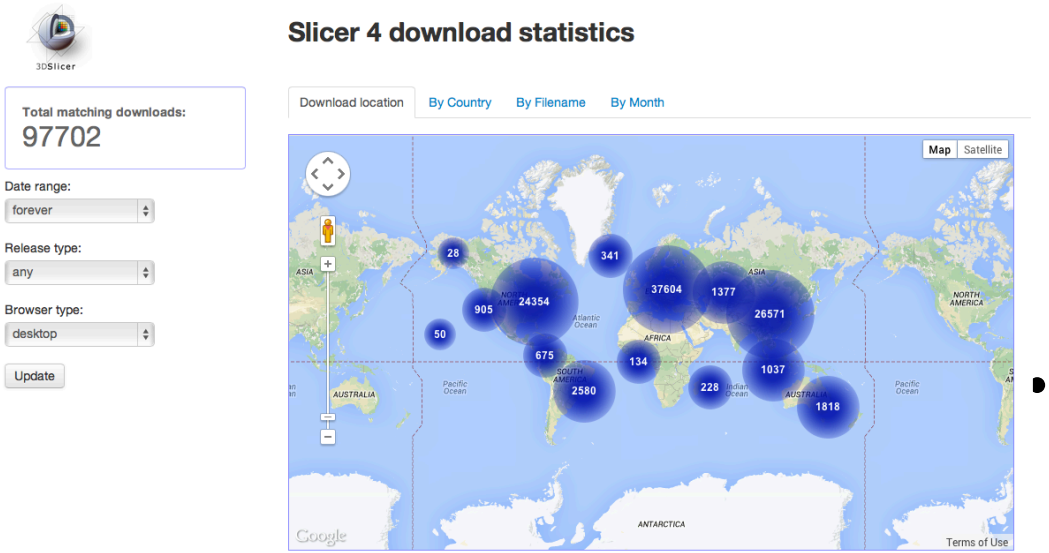
3DSlicer History



- 1997: Slicer started as a research project between the Surgical Planning Lab (Harvard) and the CSAIL (MIT)
- 2013: Multi-institution effort to share the latest advances in image analysis with the clinical and scientific community

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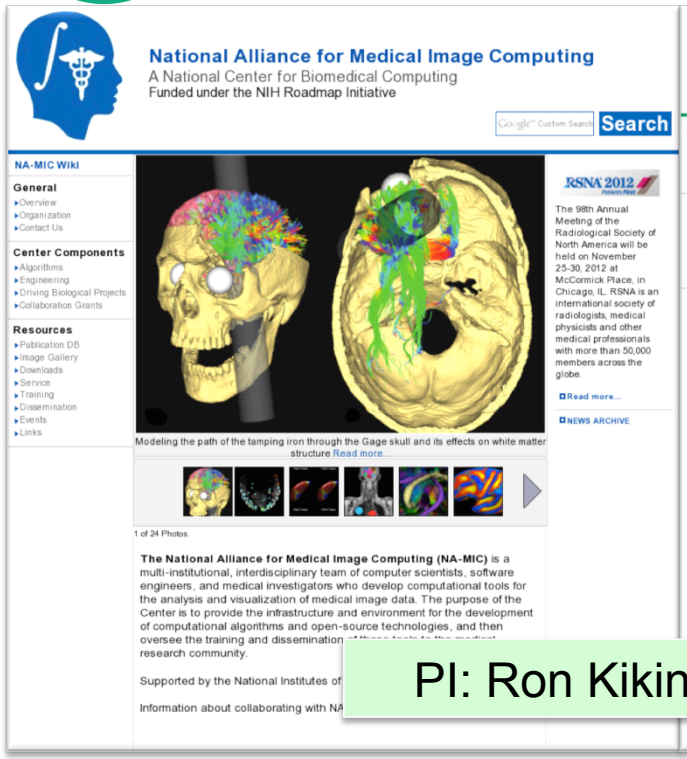
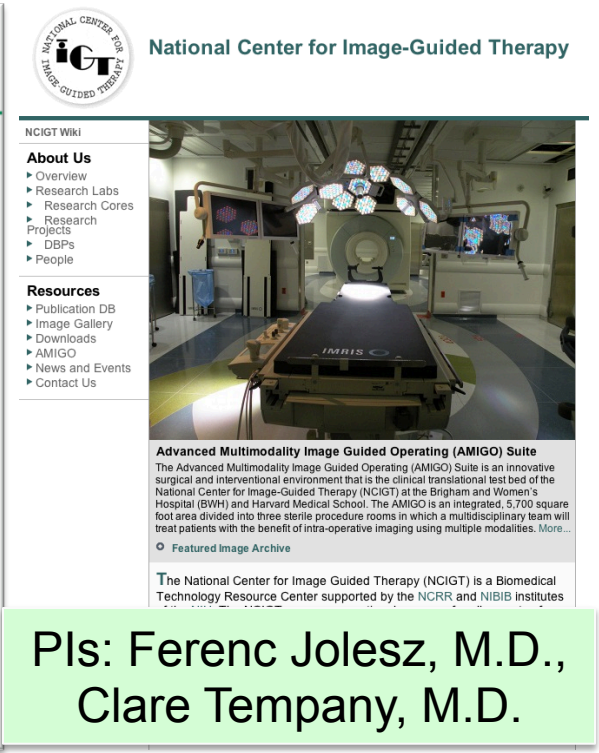
A multi-institution: NA-MIC, NAC, NCIGT





PI: Ron Kikinis, M.D.

PIs: Ferenc Jolesz, M.D., Clare Tempany, M.D.

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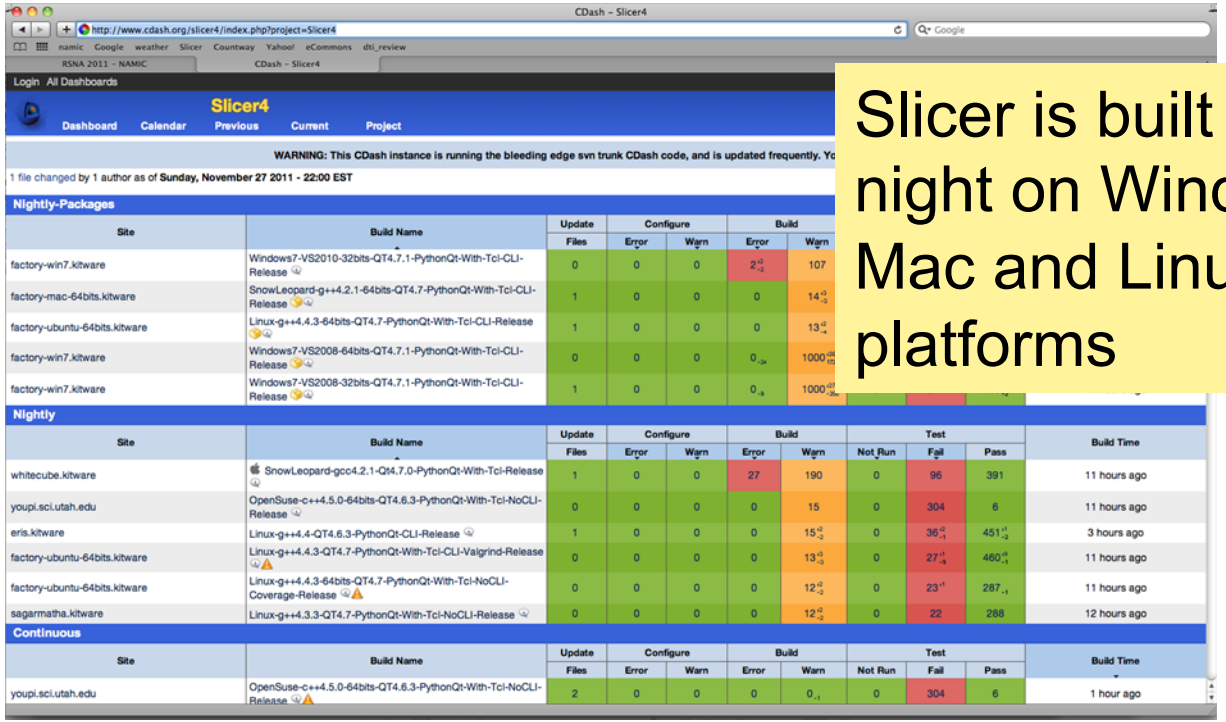
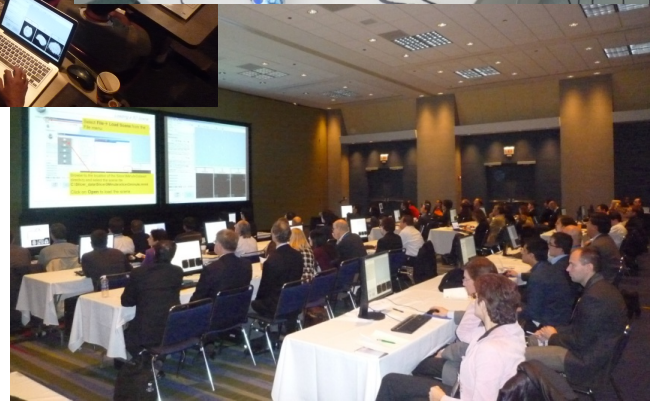
Slicer: Behind the scenes



Slicer is built every night on Windows, Mac and Linux platforms

Slicer Training events



- Hands-on training workshops at national and international venues
- More than 2,700 clinicians, clinical researchers and scientists trained since 2005

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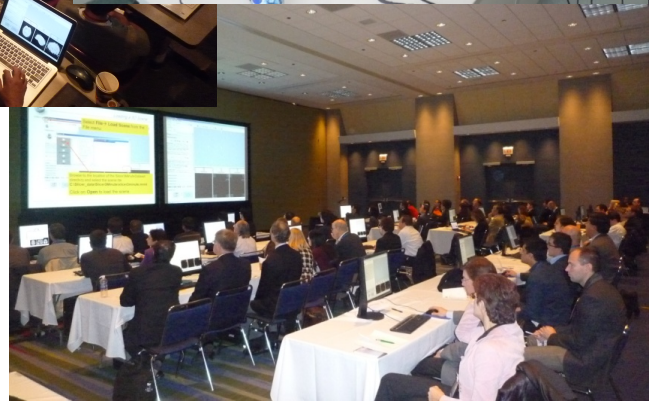
Slicer Training events



RSNA 2011

Major international conferences

- **RSNA** 2008, 2009, 2010, 2011, 2012,2013
- **MICCAI** 2008, 2009, 2011, 2012,2013
- **SfN** 2009, 2011
- **SPIE** 2012, 2013
- **CAOS** 2010
- **CARS** 2010, 2012, 2013

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RSNA Activities

Hands-on refresher courses

- 3D Visualization of DICOM images for Radiology Applications
- Quantitative Imaging for Clinical Research and Practice

Quantitative Imaging Reading Room Exhibit

- 3DSlicer: An Open Source Platform for Segmentation, Registration, Quantitative Imaging, and 3D Visualization of Multi-Modal Image Data.

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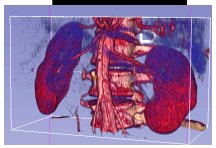

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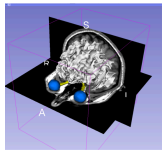

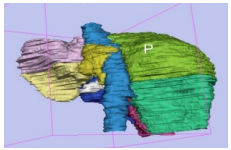

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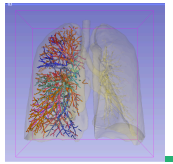

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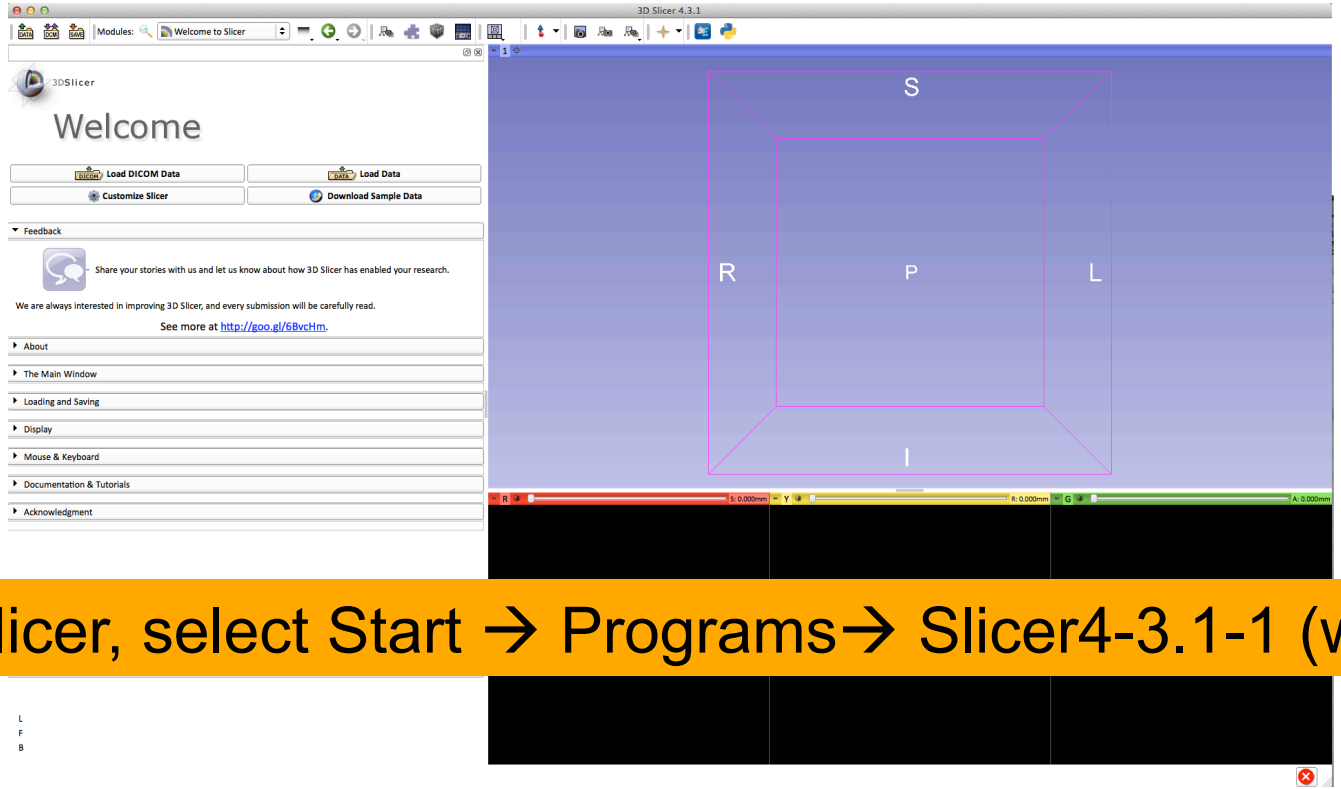
Welcome to Slicer4



To start Slicer, select Start → Programs→ Slicer4-3.1-1 (win64)

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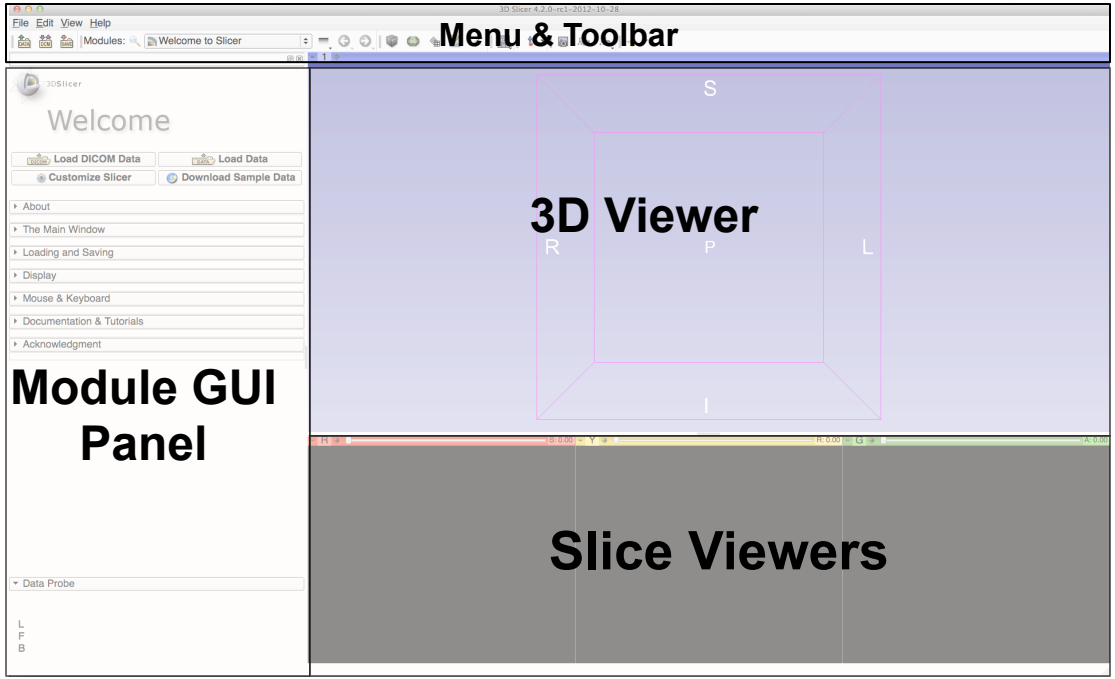
Navigating the Application GUI

The Graphic User Interface (GUI) of Slicer4 integrates **four components:**

- the Menu Toolbar
- the Module GUI Panel
- the 3D Viewer
- the Slice Viewer



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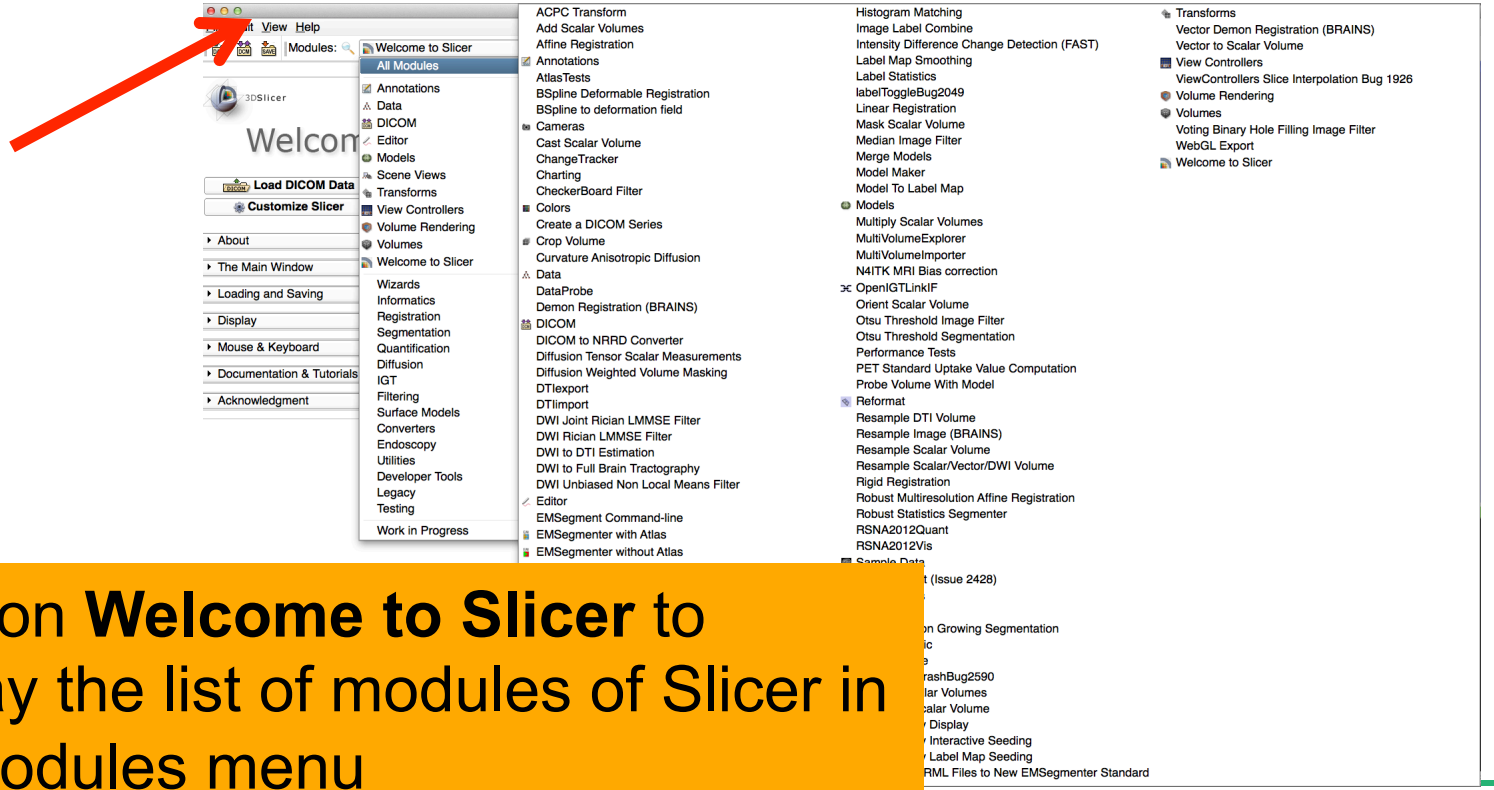
Welcome to Slicer4.3.1.1



Click on **Welcome to Slicer** to display the list of modules of Slicer in the Modules menu

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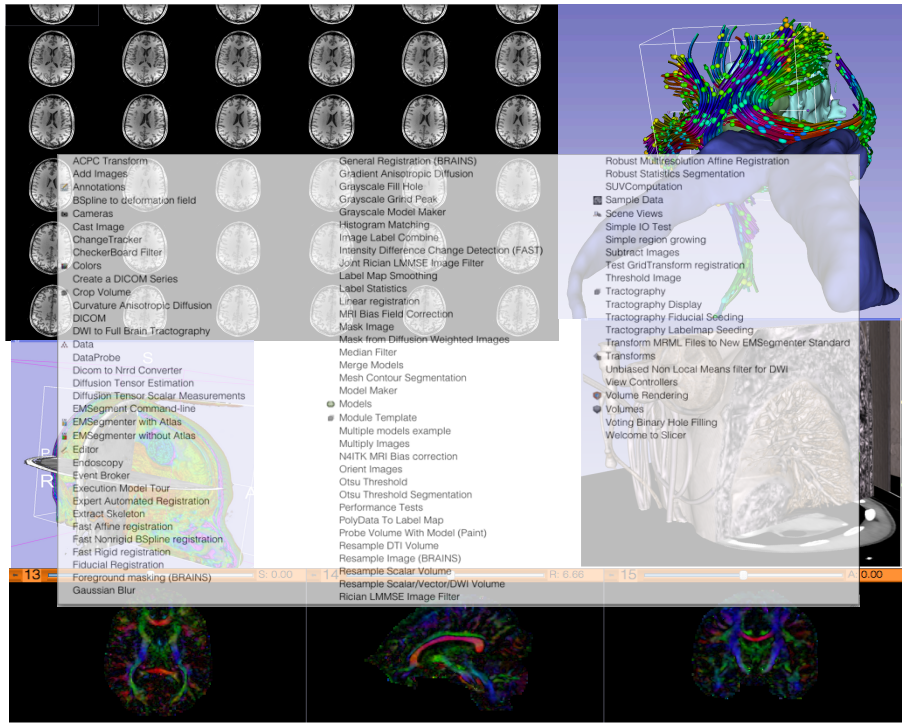
Welcome to Slicer4



Slicer4.3.1 contains more than 100 modules for image segmentation, registration and 3D visualization of medical imaging data

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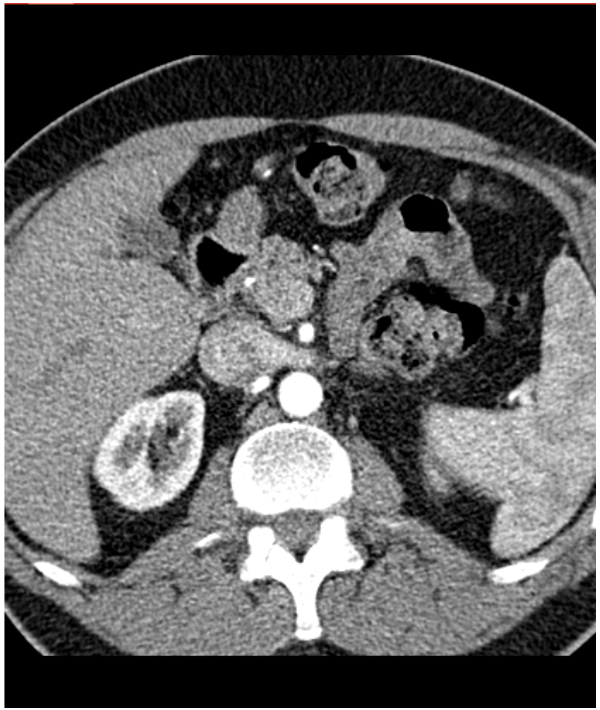

Part 1:

Loading a DICOM Volume

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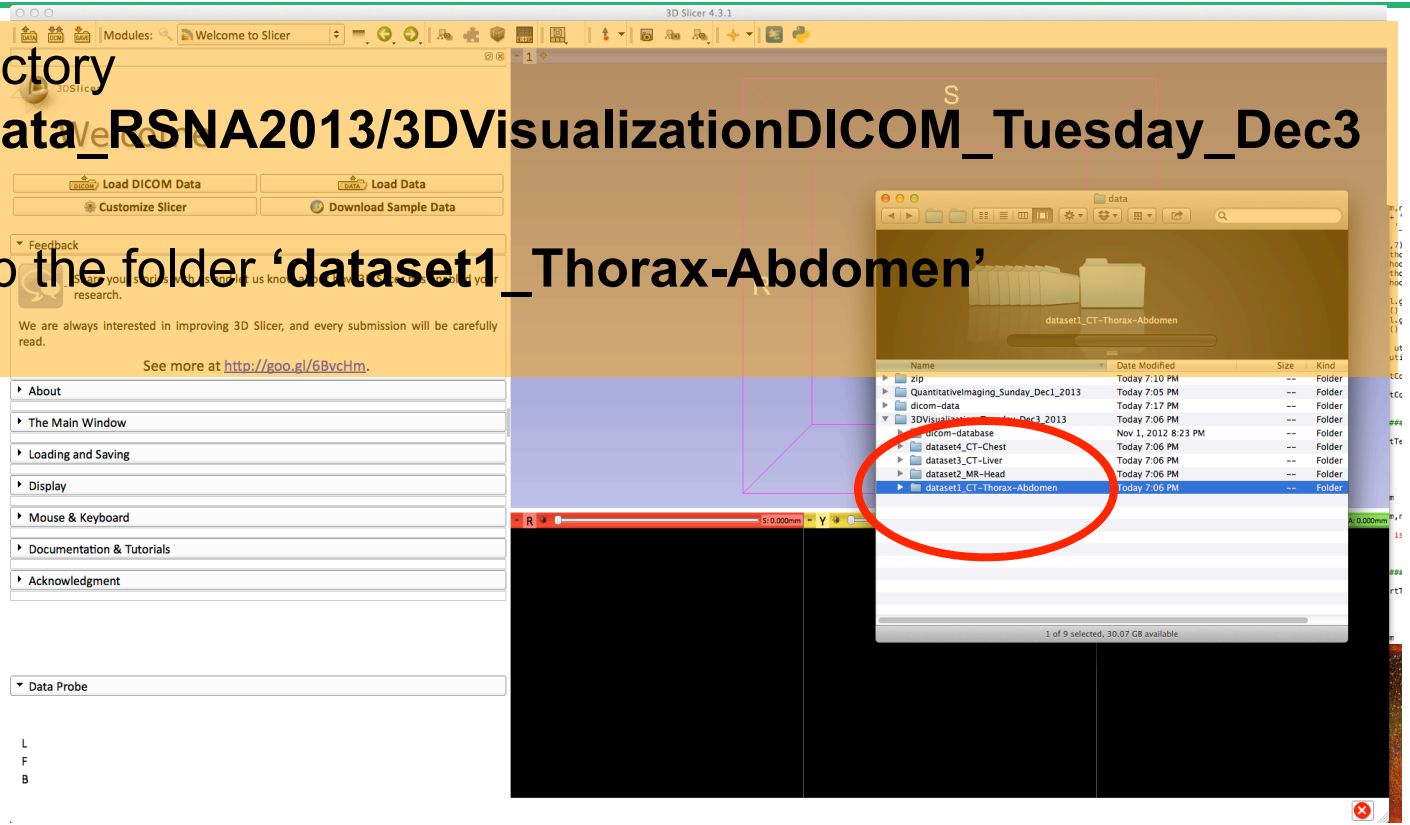
Loading a DICOM volume

Open the directory
C:/3DSlicerData_RSNA2013/3DVisualizationDICOM_Tuesday_Dec3

Drag and drop the folder **‘dataset1_Thorax-Abdomen’** into Slicer



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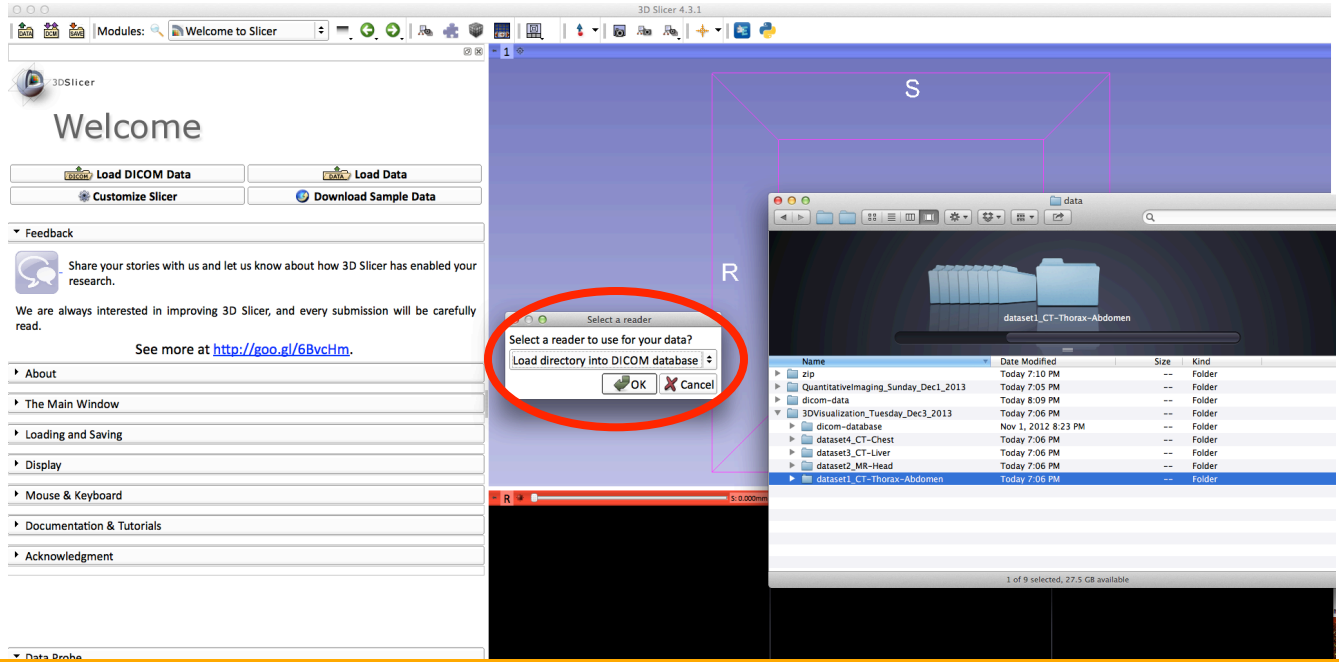
Loading a DICOM volume



A pop-up window appears:
Select **Load directory into DICOM database** and click on **OK**

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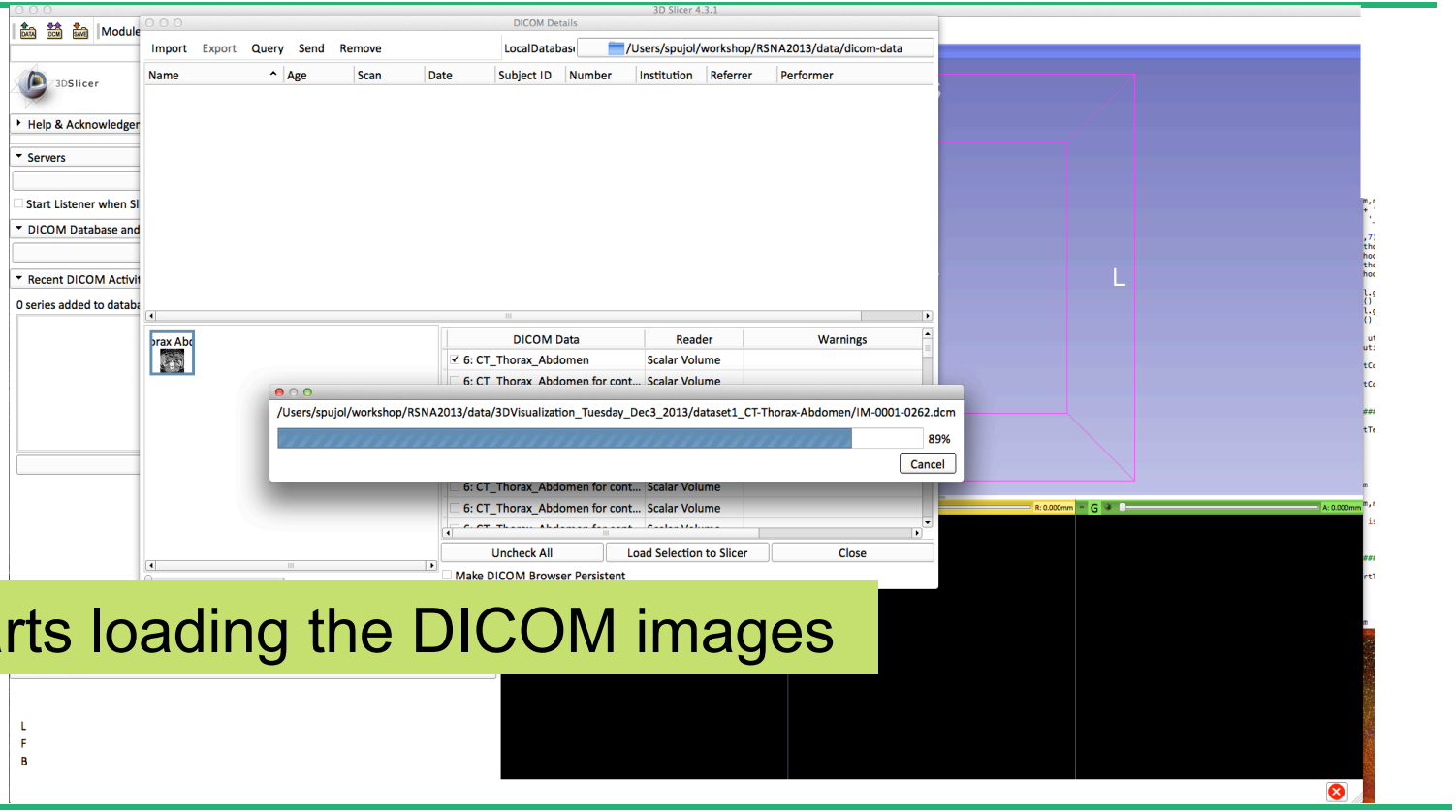
Loading a DICOM volume



Slicer starts loading the DICOM images

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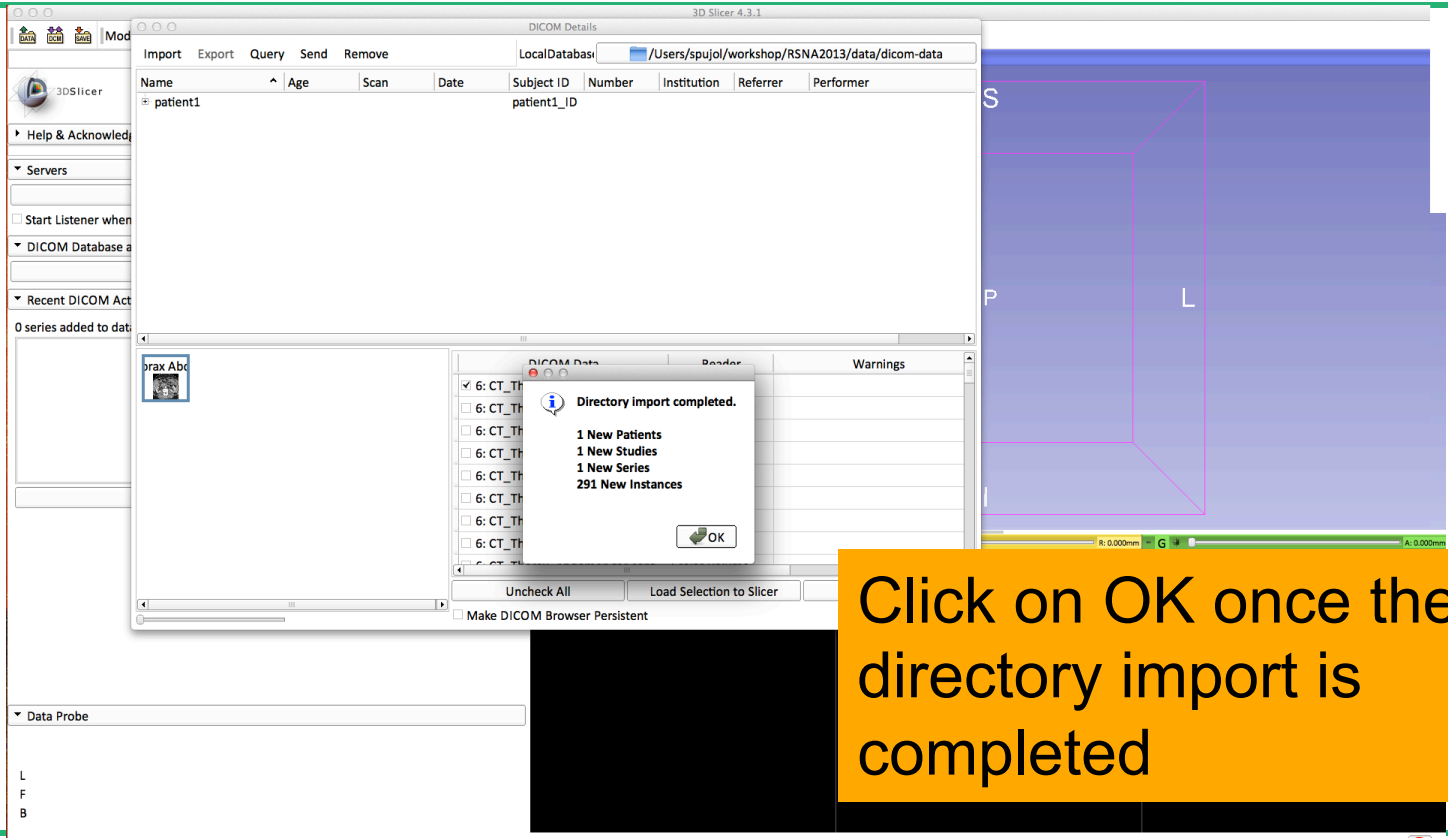
Loading a DICOM volume



Click on OK once the directory import is completed

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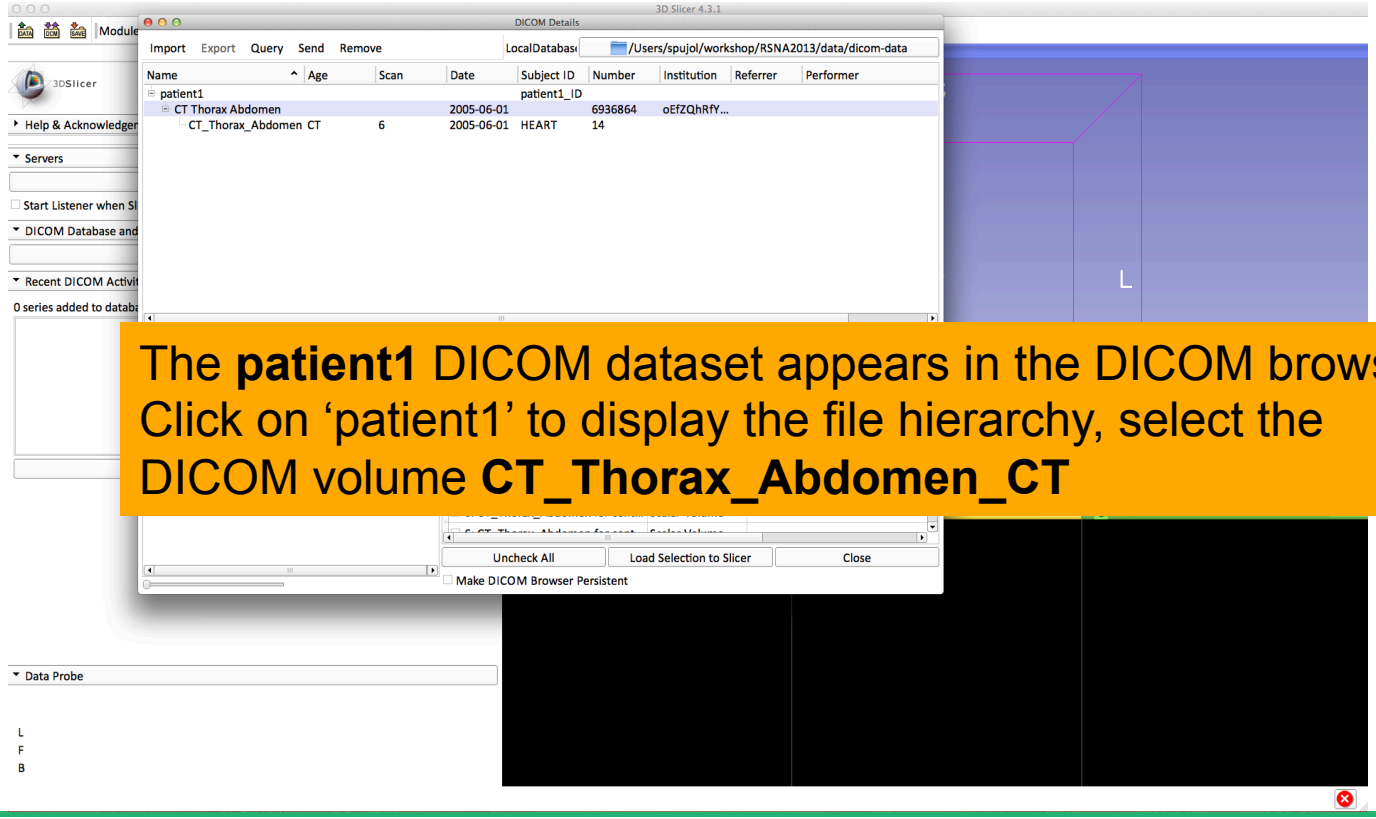
Loading a DICOM volume



The **patient1** DICOM dataset appears in the DICOM browser. Click on ‘patient1’ to display the file hierarchy, select the DICOM volume **CT_Thorax_Abdomen_CT**

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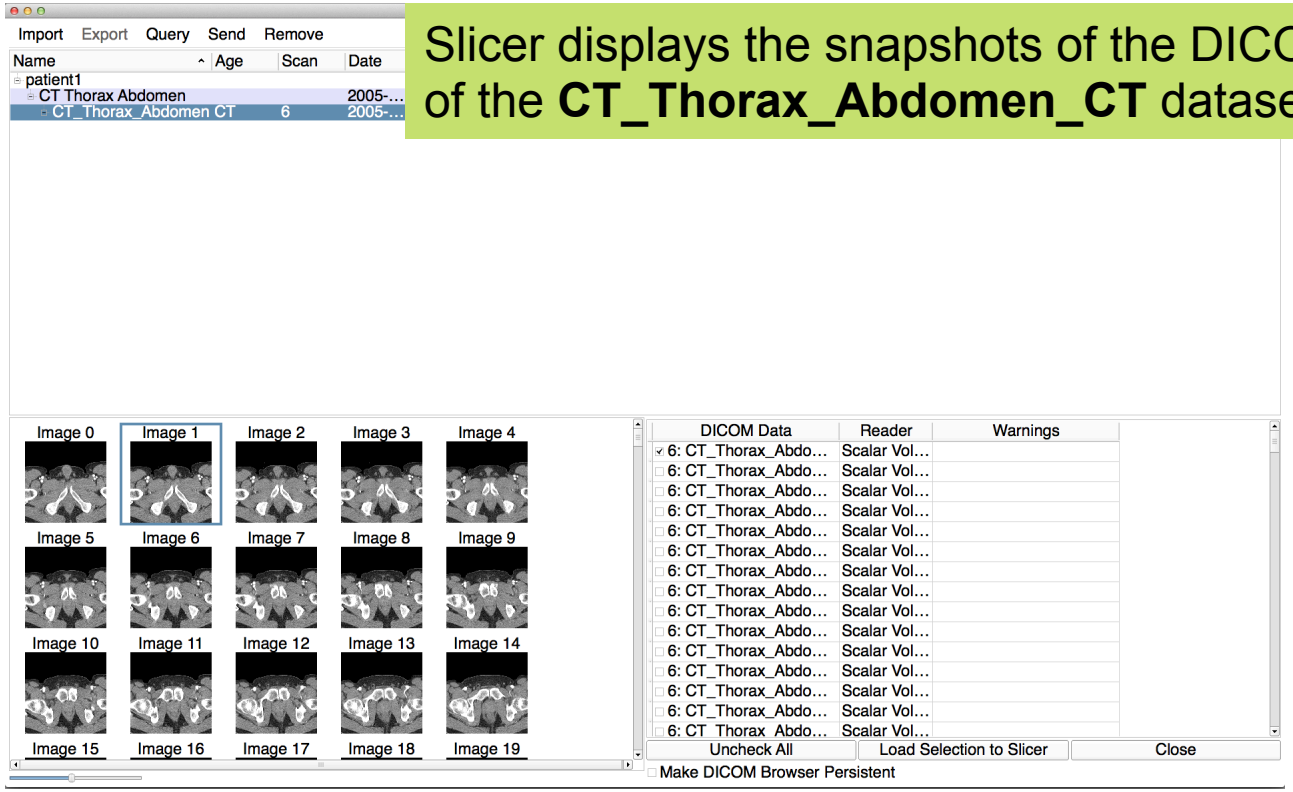
Loading a DICOM volume



Slicer displays the snapshots of the DICOM images of the **CT_Thorax_Abdomen_CT** dataset

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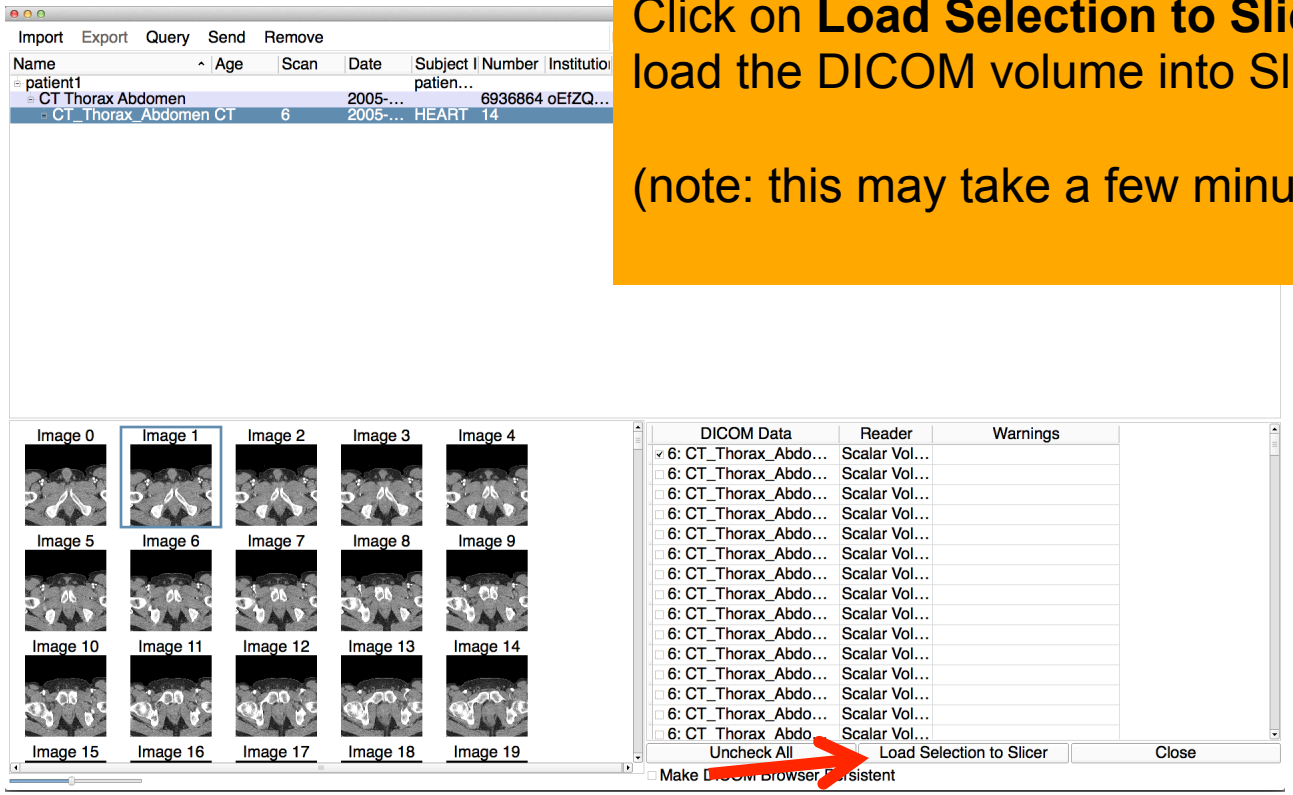
Loading a DICOM volume

Click on **Load Selection to Slicer** to load the DICOM volume into Slicer

(note: this may take a few minutes)



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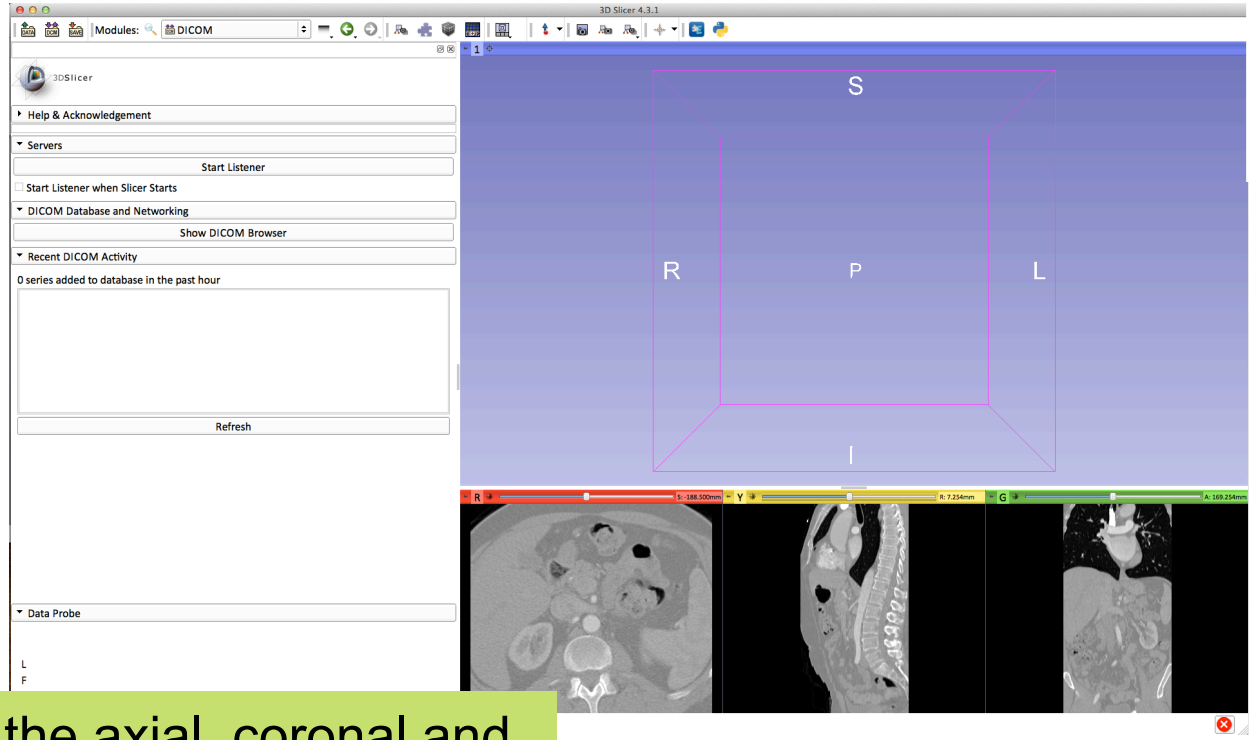
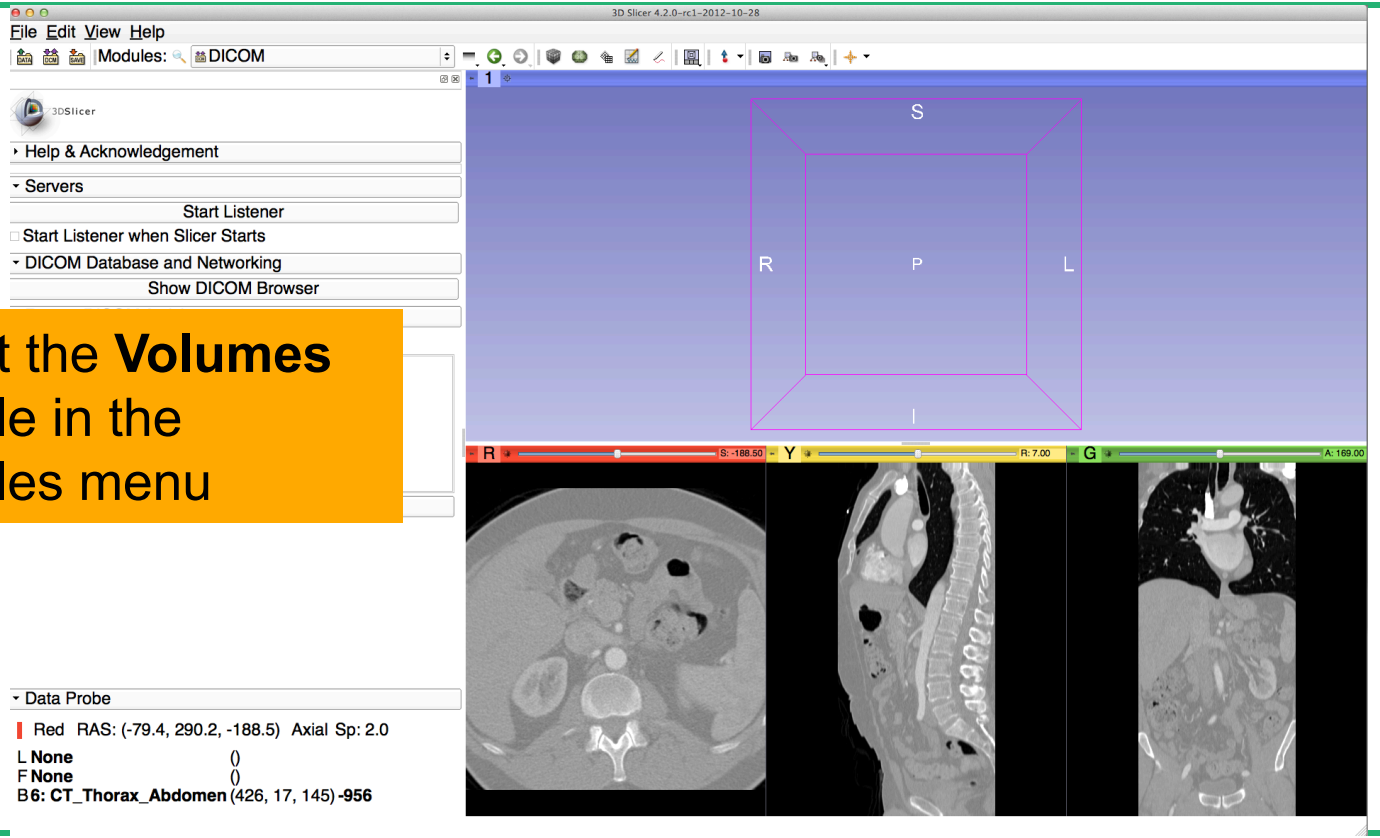
Loading a DICOM volume



Slicer displays the axial, coronal and sagittal slices of the DICOM dataset

Loading a DICOM volume



Select the **Volumes** module in the modules menu

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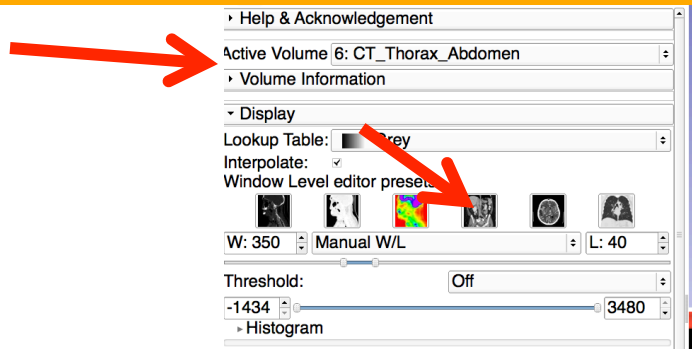
Loading a DICOM volume

Select the Active Volume **6:CT_Thorax_Abdomen**



Slicer has a series of window/level presets available

Click on the Window Level Preset **CT-abdomen,** or adjust manually the Window and Level using the Manual W/L slider

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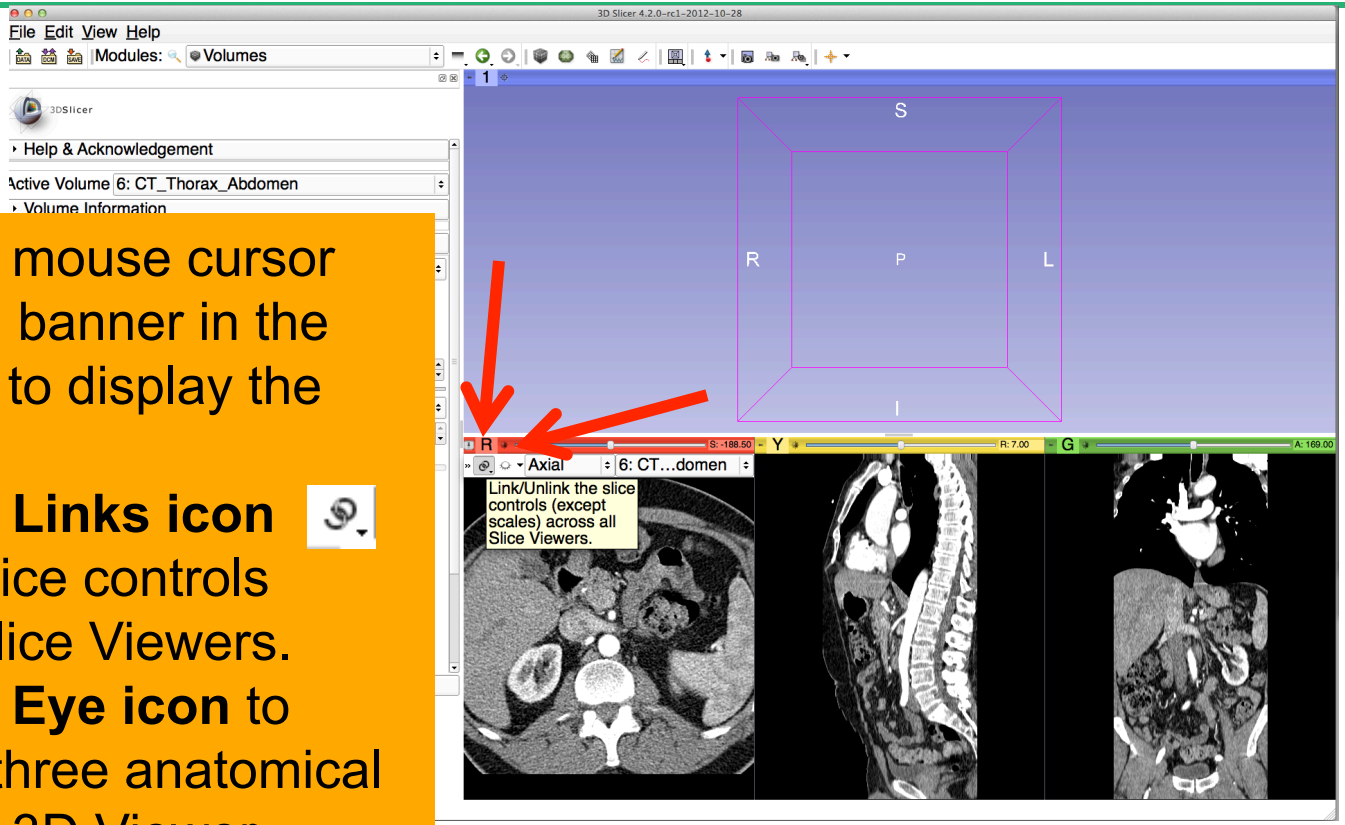
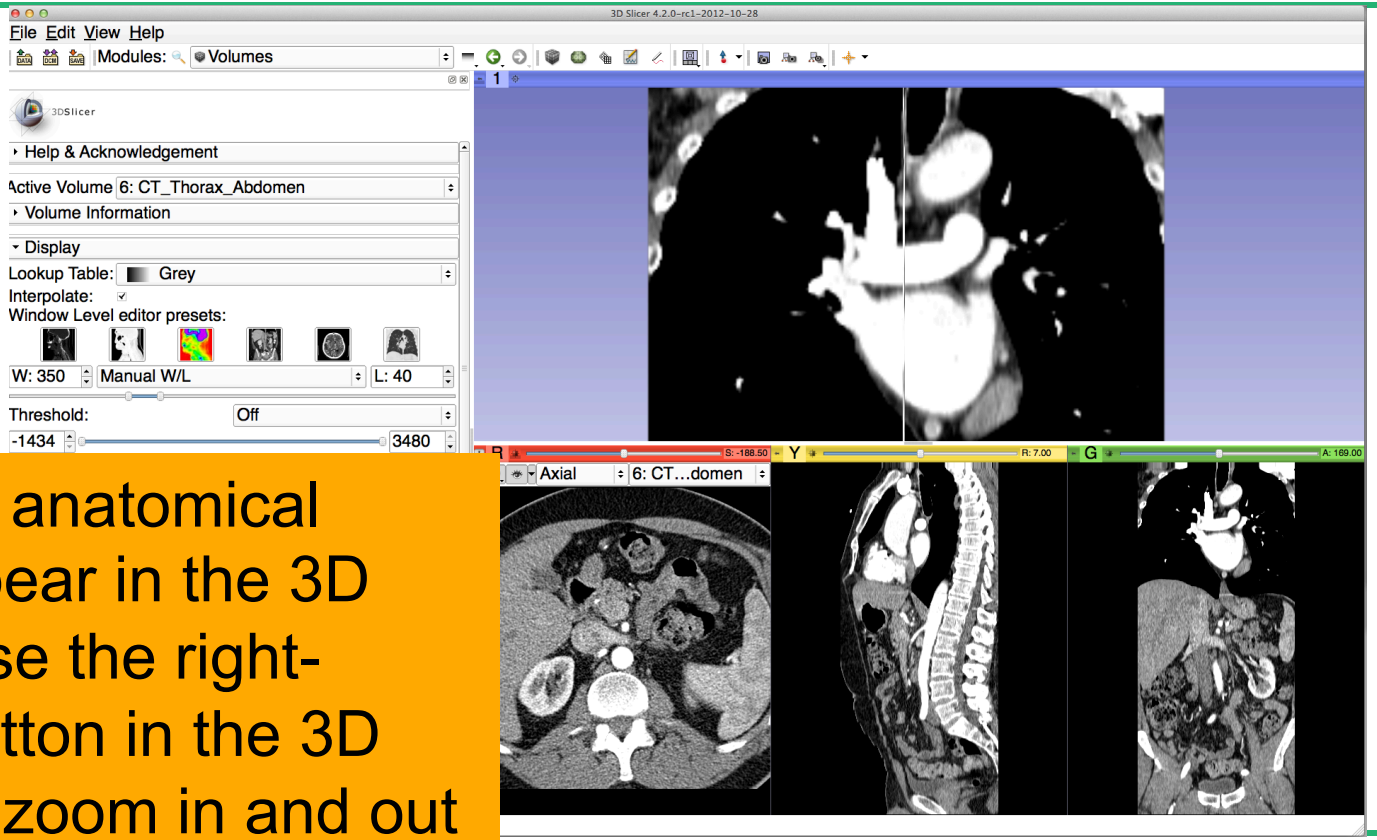
Loading a DICOM volume



Position the mouse cursor over the red banner in the Red Viewer to display the slice menu.
Click on the **Links icon** to link the slice controls across all Slice Viewers.
Click on the **Eye icon** to display the three anatomical slices in the 3D Viewer

Loading a DICOM volume



The three anatomical slices appear in the 3D viewer. Use the right-mouse button in the 3D Viewer to zoom in and out

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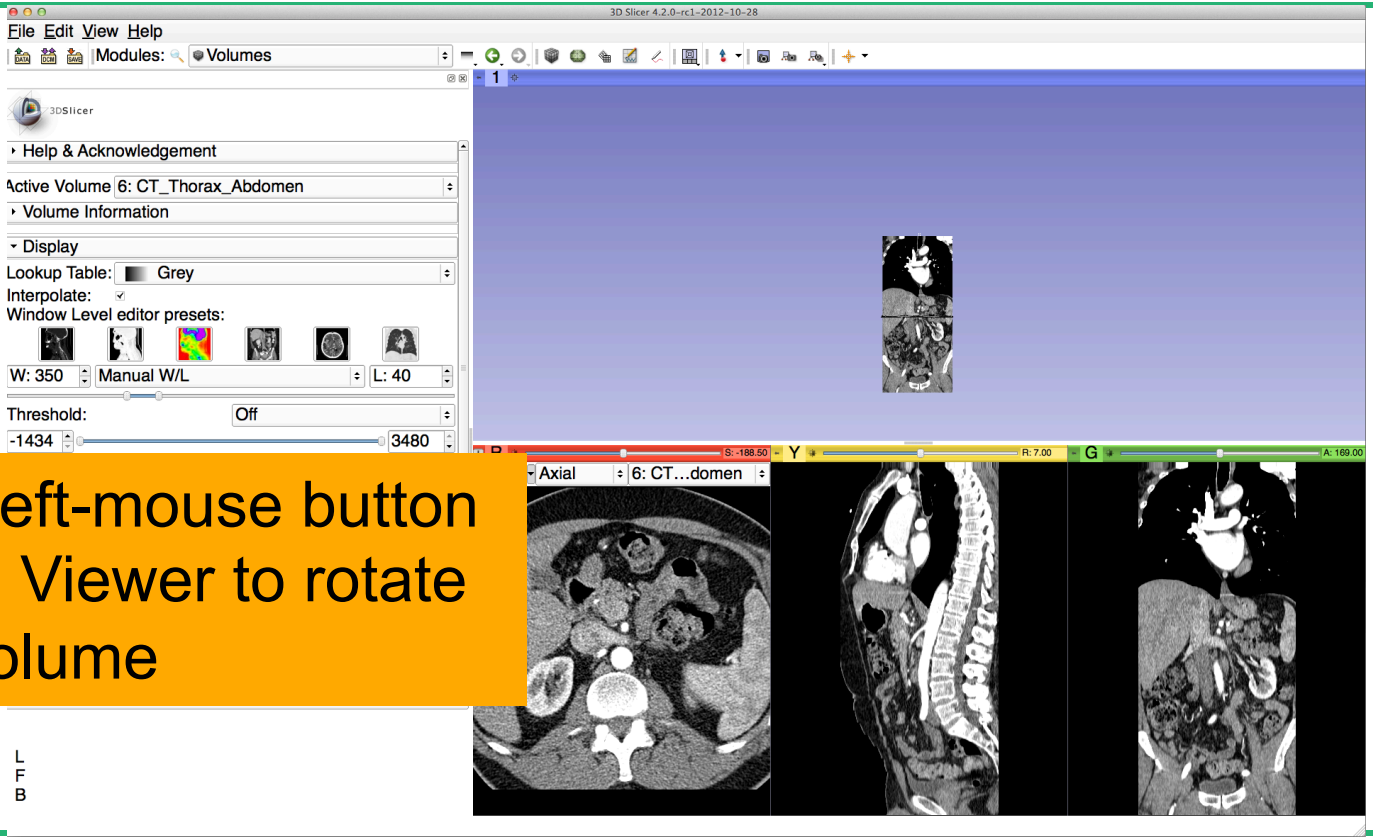
Loading a DICOM volume



Use the left-mouse button in the 3D Viewer to rotate the 3D volume

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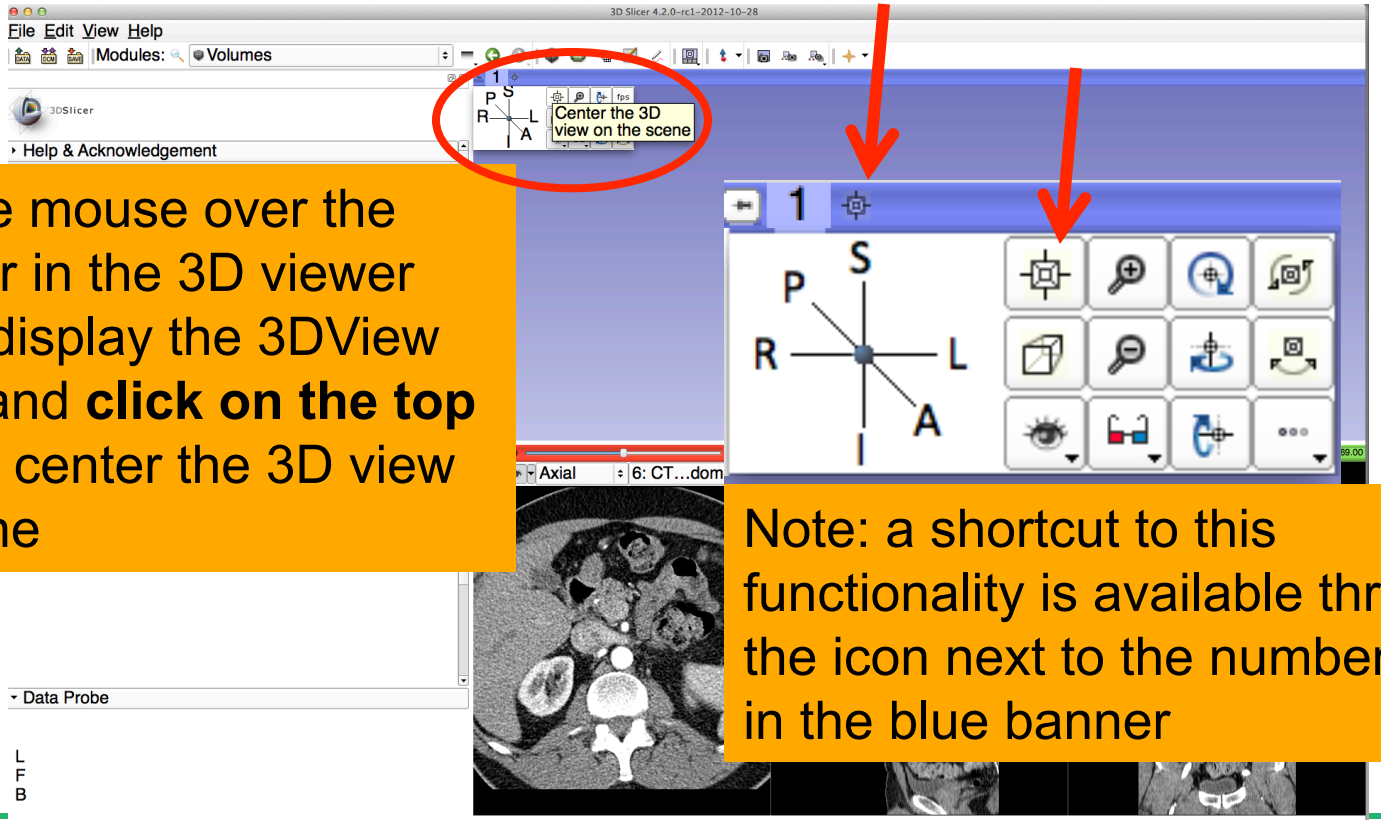
Loading a DICOM volume



Position the mouse over the blue banner in the 3D viewer window to display the 3DView controller, and **click on the top left icon** to center the 3D view on the scene

Note: a shortcut to this functionality is available through the icon next to the number ‘1’ in the blue banner

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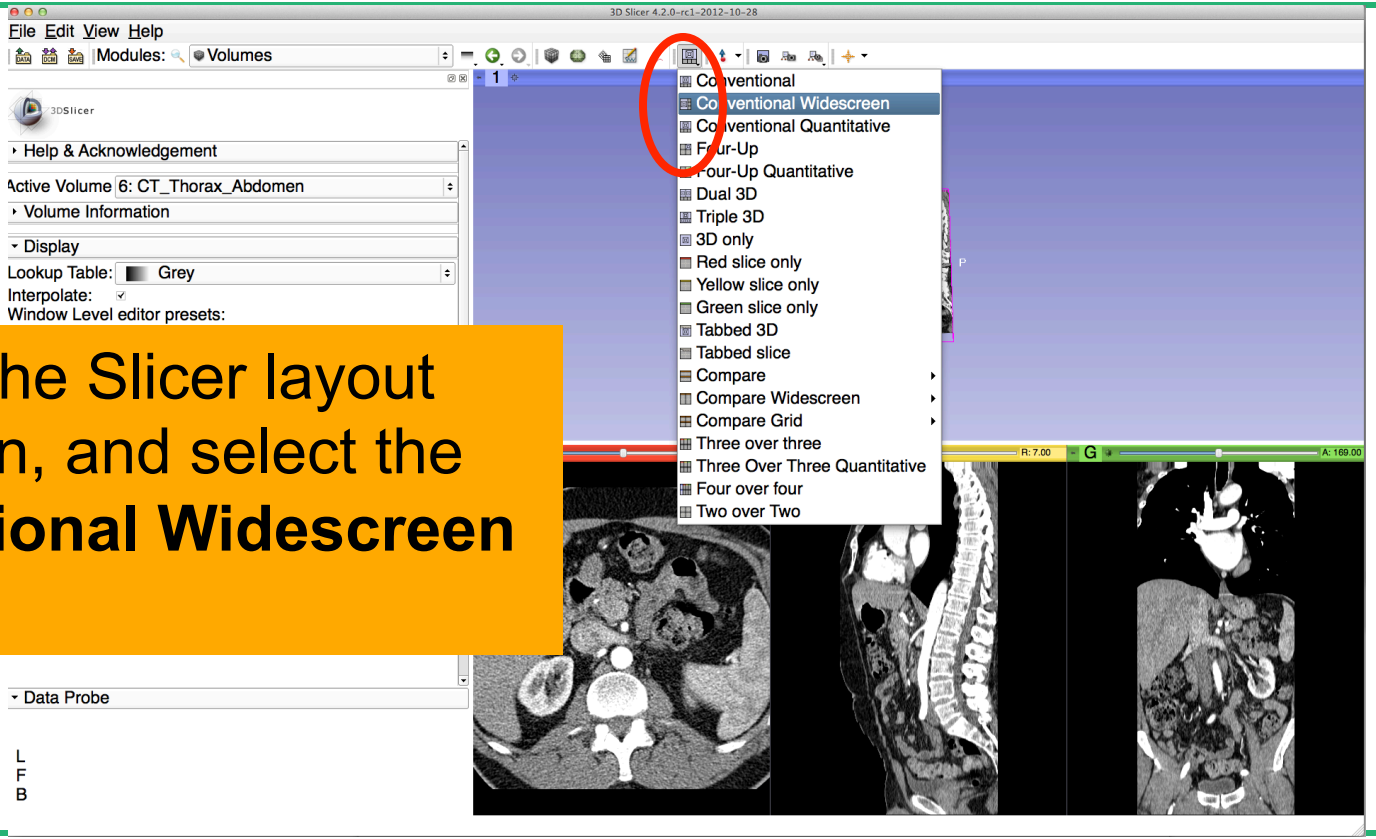
Loading a DICOM volume



Click on the Slicer layout menu icon, and select the **Conventional Widescreen** layout

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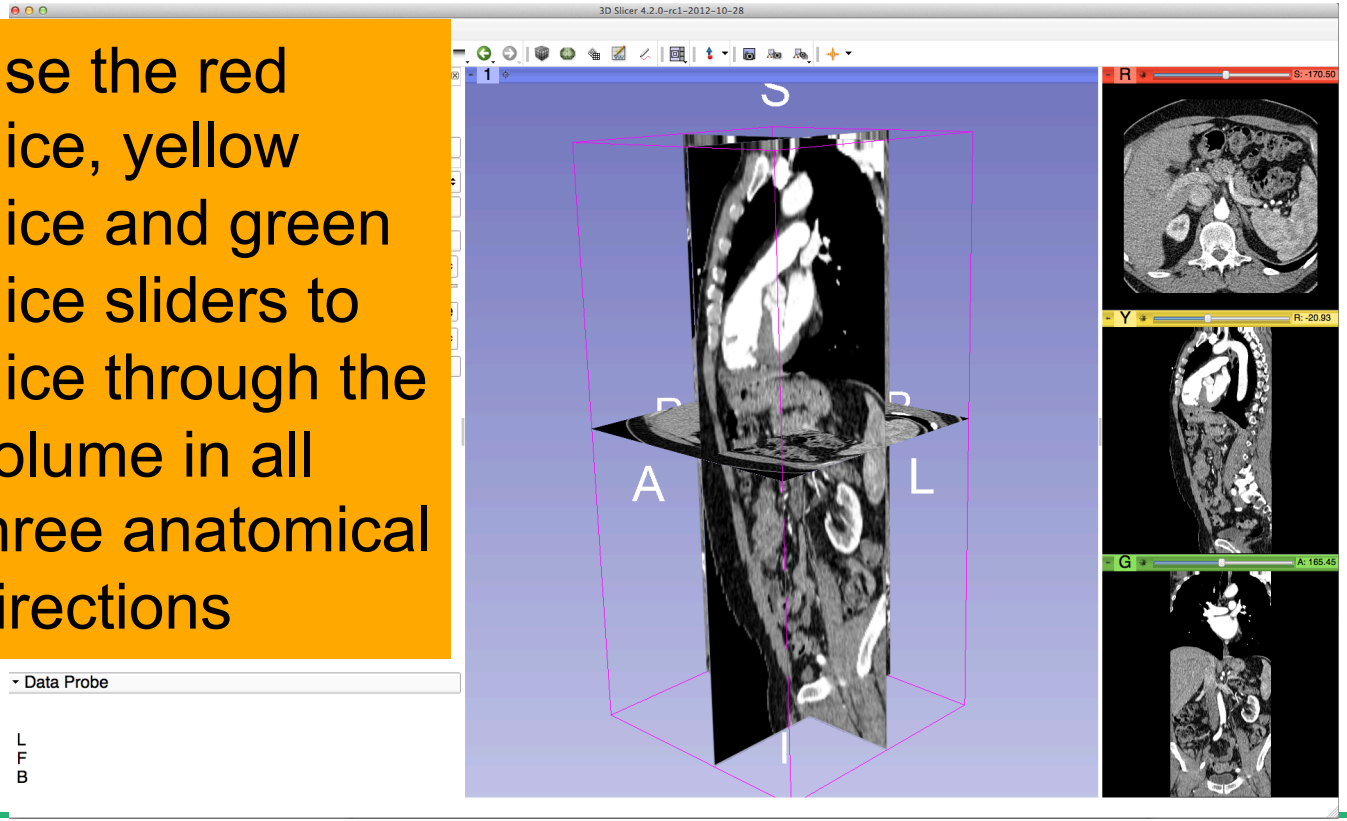
Loading a DICOM volume

Use the red slice, yellow slice and green slice sliders to slice through the volume in all three anatomical directions



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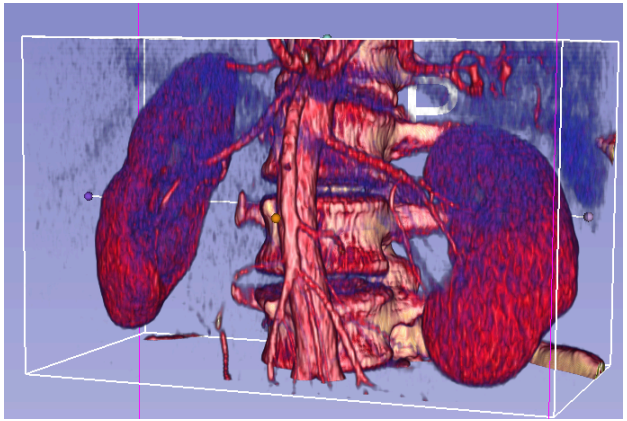

3D Interactive exploration of thoraco-abdominal CT data using Volume Rendering

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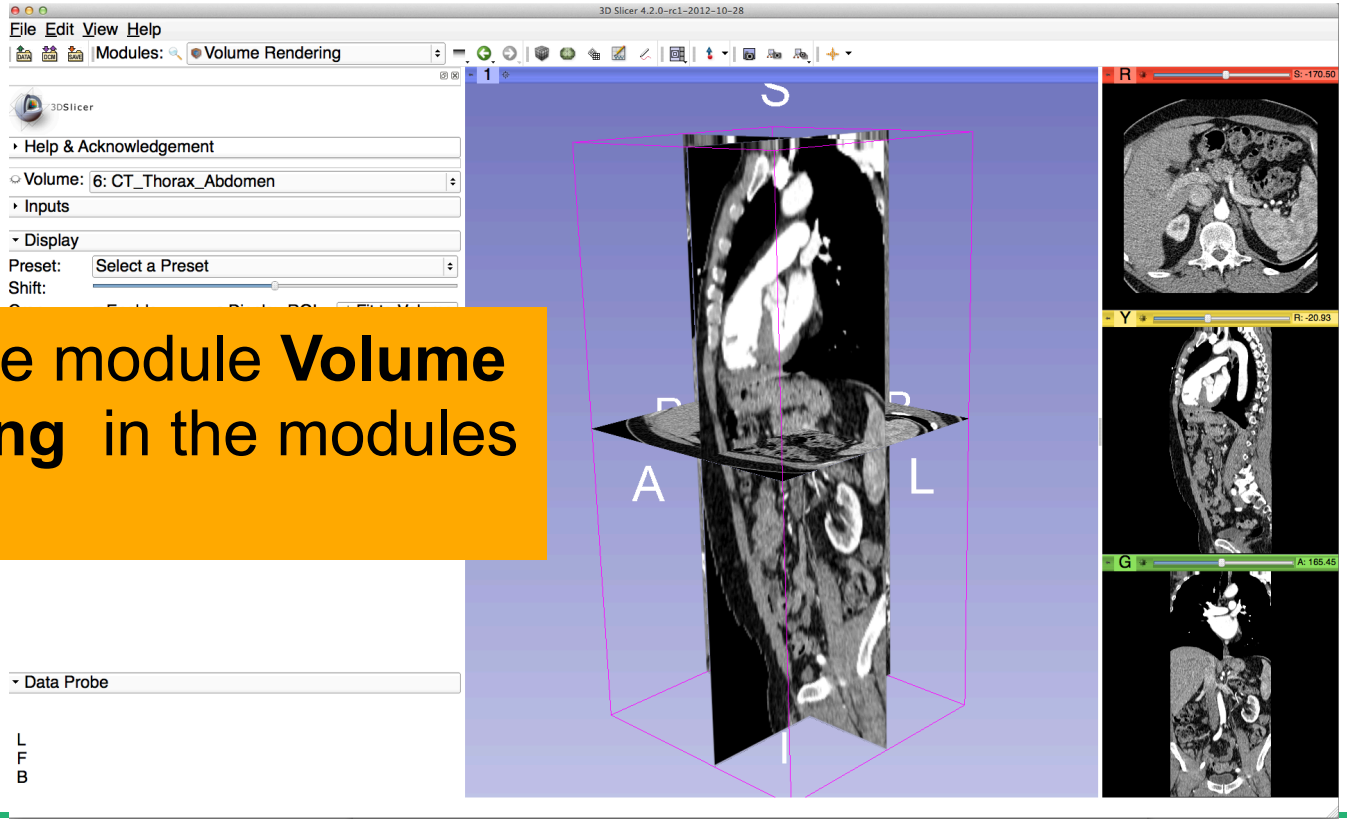
Volume Rendering



Select the module **Volume Rendering** in the modules menu

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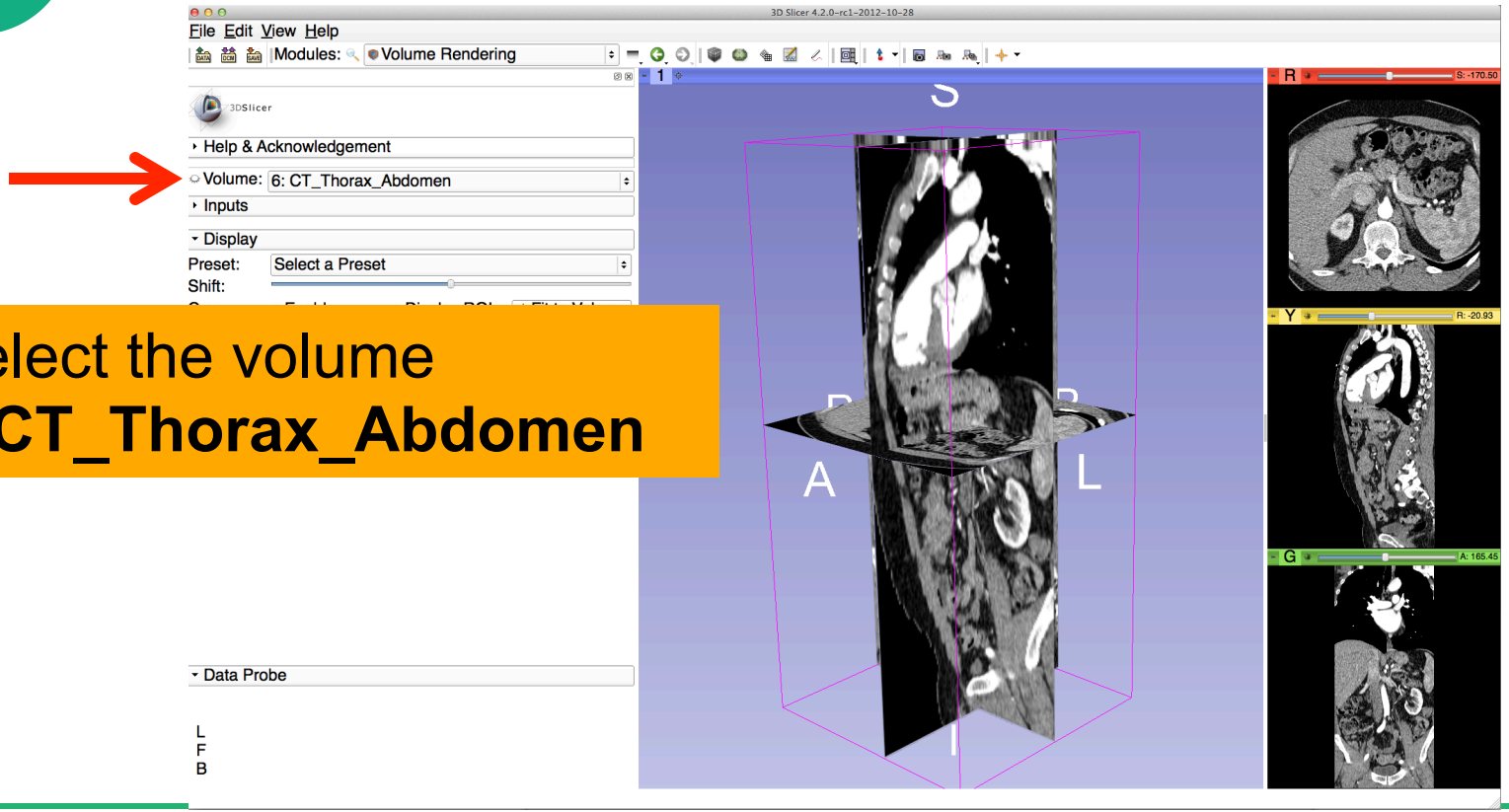
Volume Rendering



Select the volume
6:CT_Thorax_Abdomen

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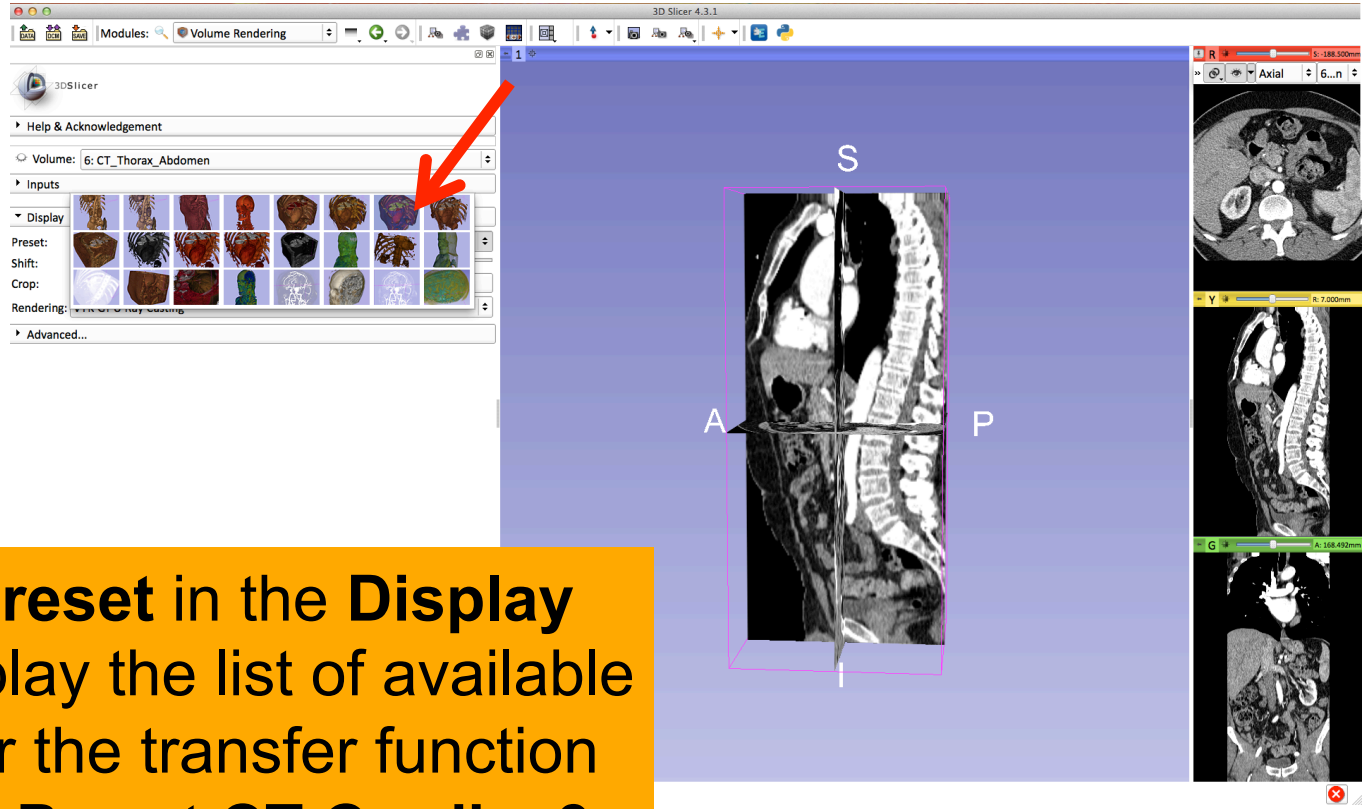
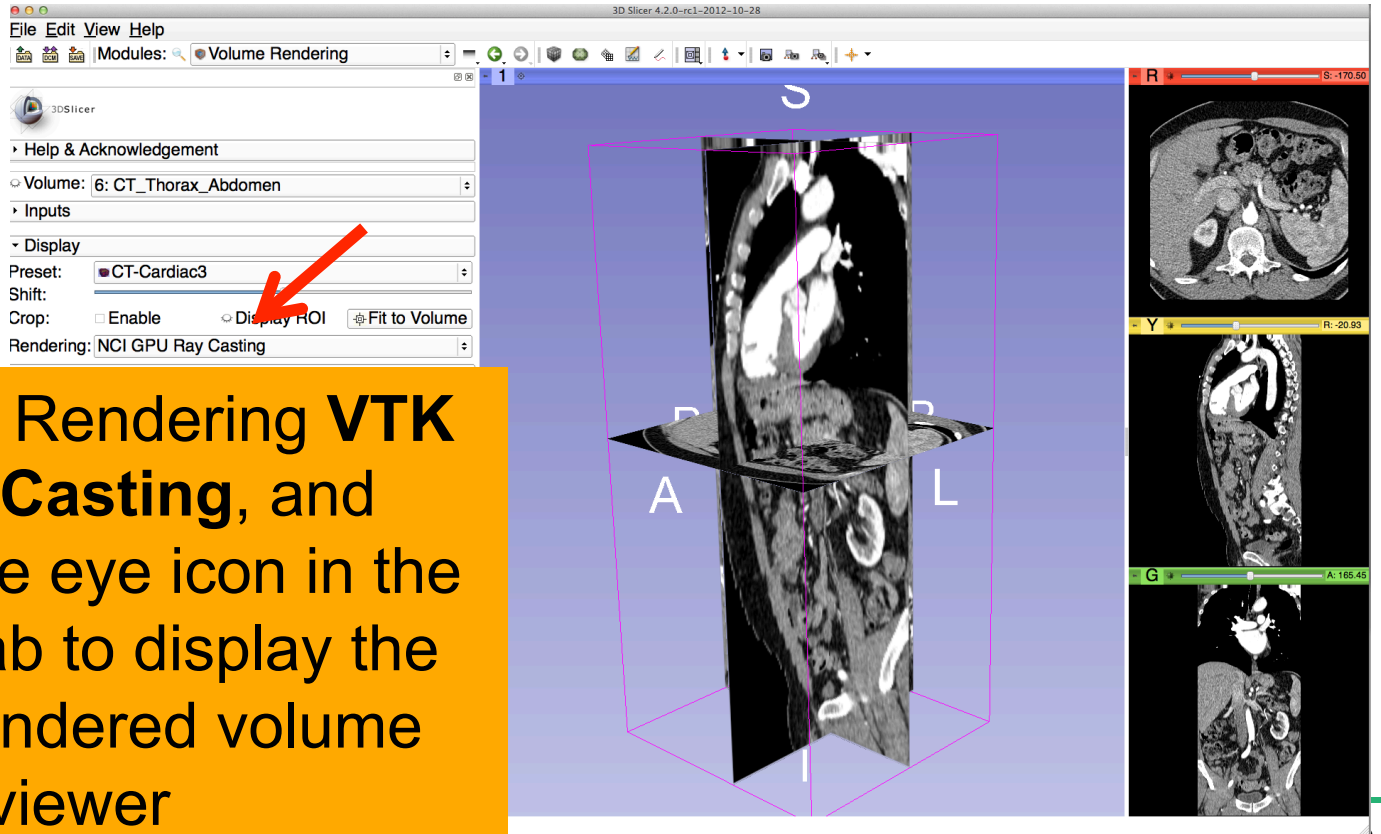
Volume Rendering



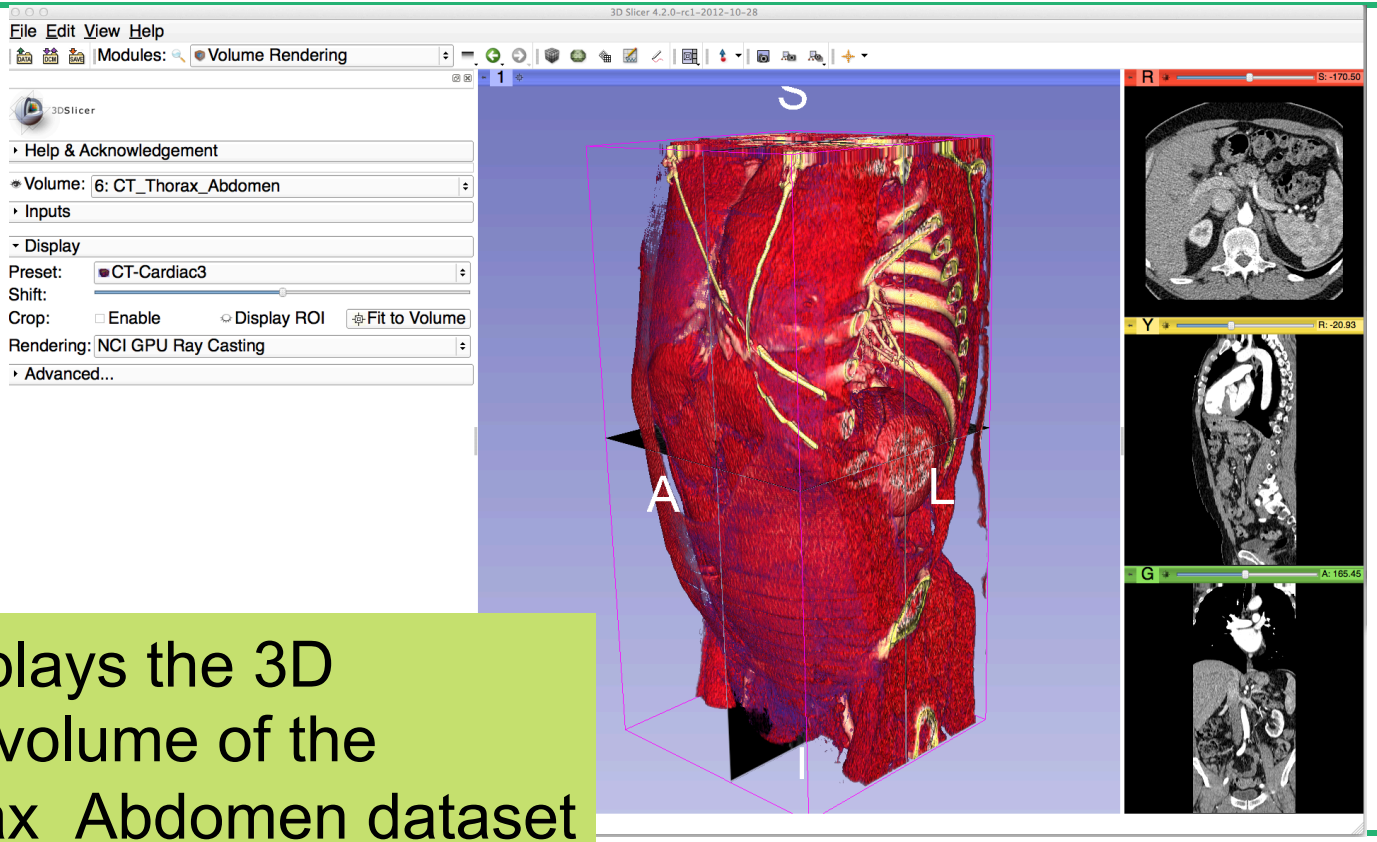
Click on **Preset** in the **Display** tab to display the list of available presets for the transfer function
Select the Preset **CT-Cardiac3**

Volume Rendering



Select the Rendering **VTK CPU Ray Casting**, and click on the eye icon in the **Volume** tab to display the Volume rendered volume in the 3D viewer

Volume Rendering



Slicer displays the 3D rendered volume of the CT_Thorax_Abdomen dataset

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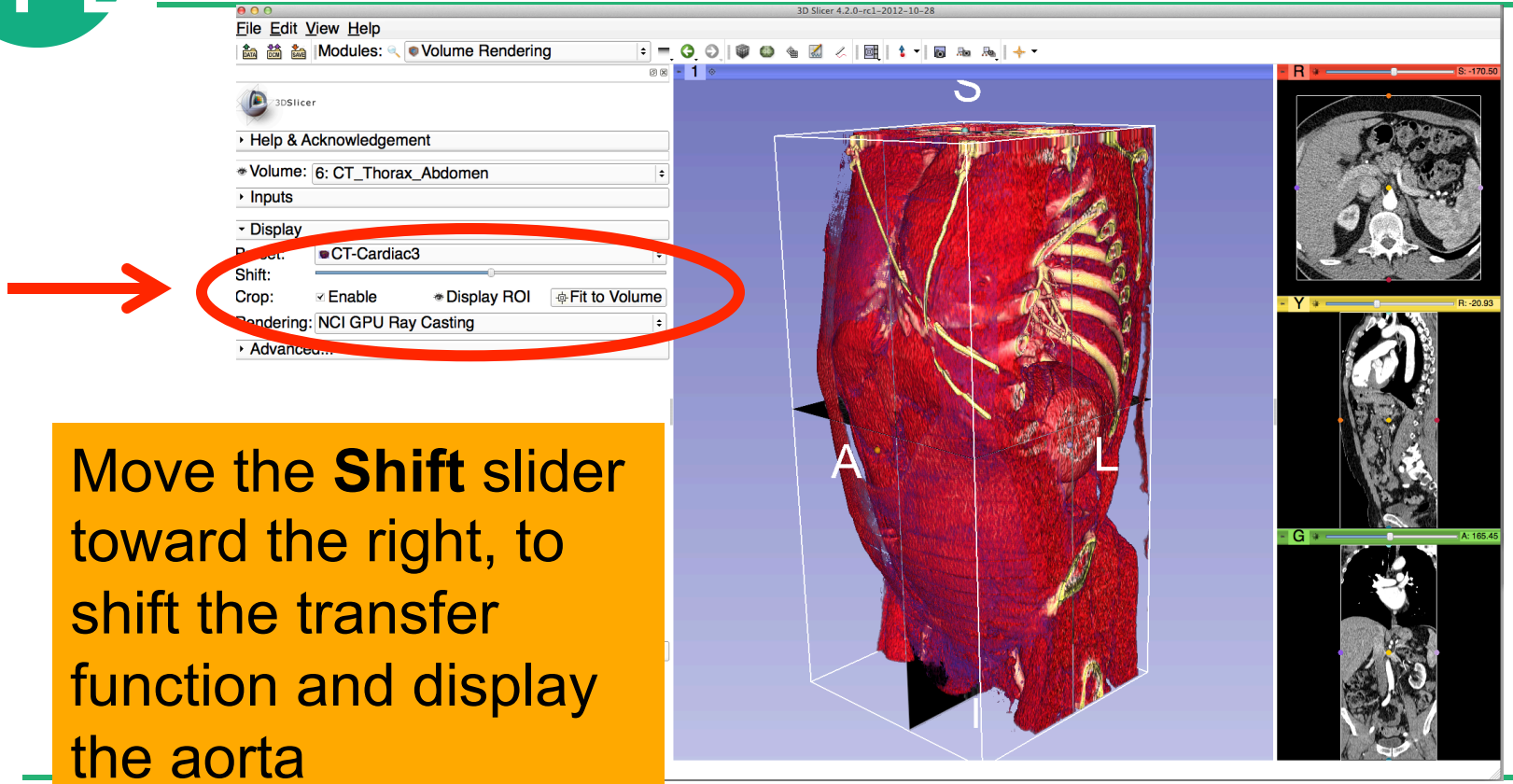
Volume Rendering



Move the **Shift** slider toward the right, to shift the transfer function and display the aorta

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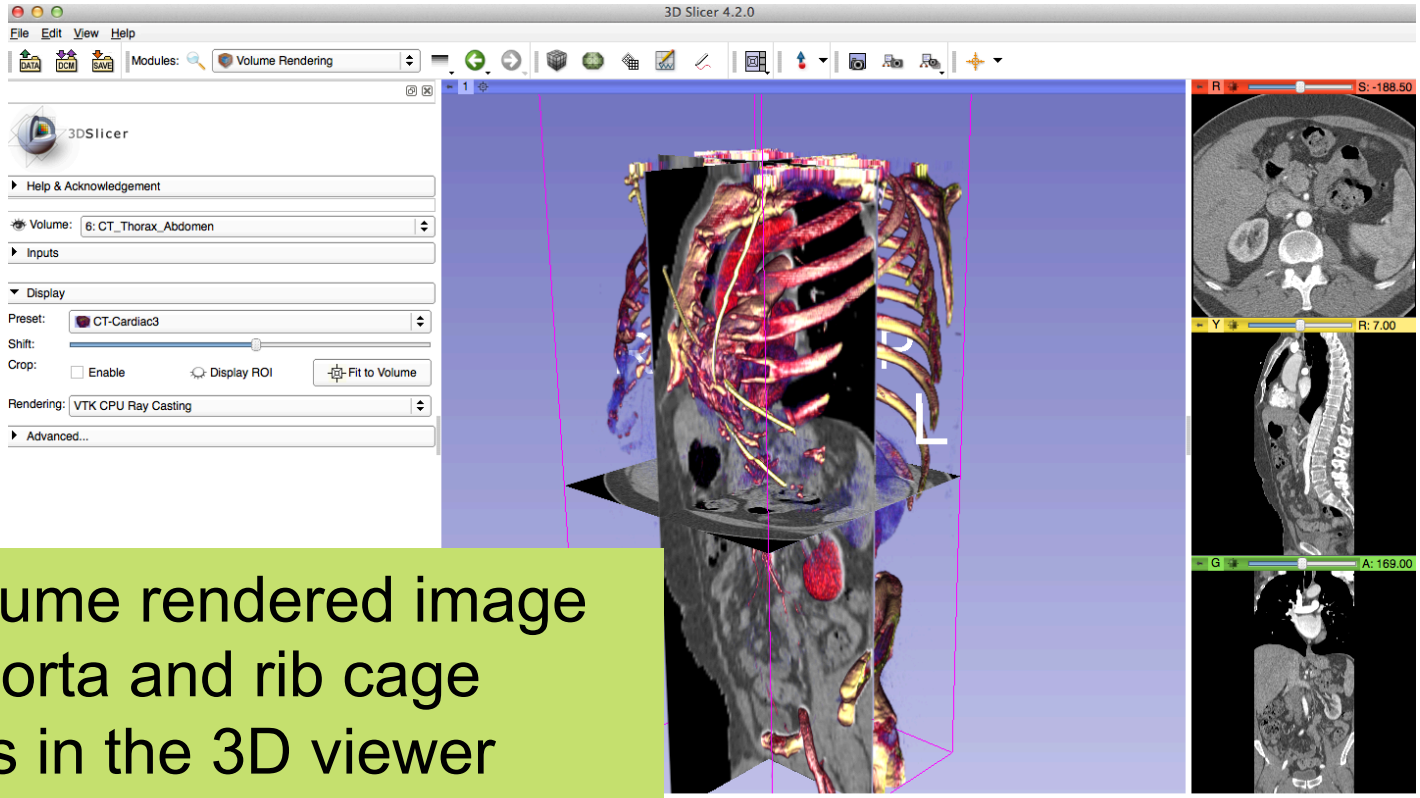
Volume Rendering



The volume rendered image of the aorta and rib cage appears in the 3D viewer

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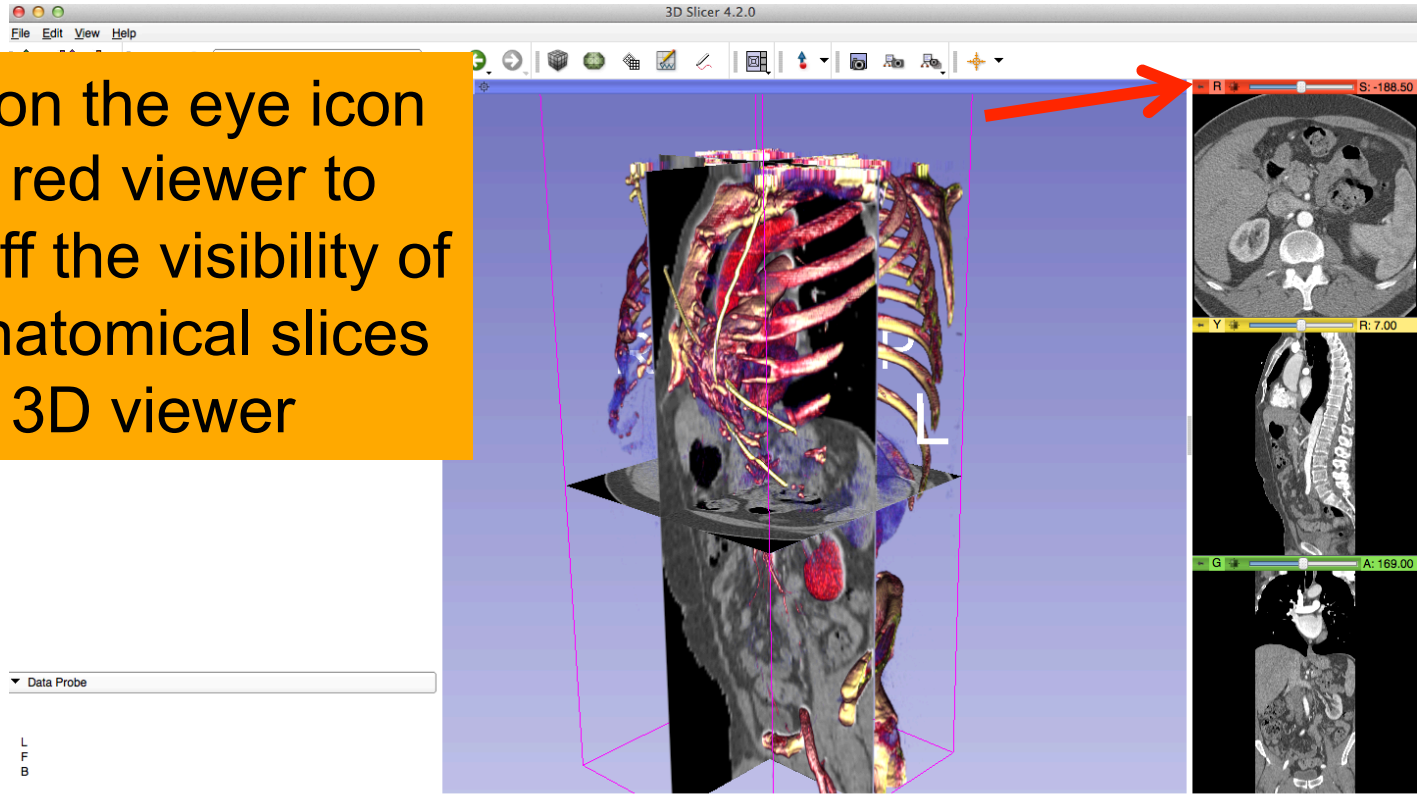
Volume Rendering

Click on the eye icon in the red viewer to turn off the visibility of the anatomical slices in the 3D viewer



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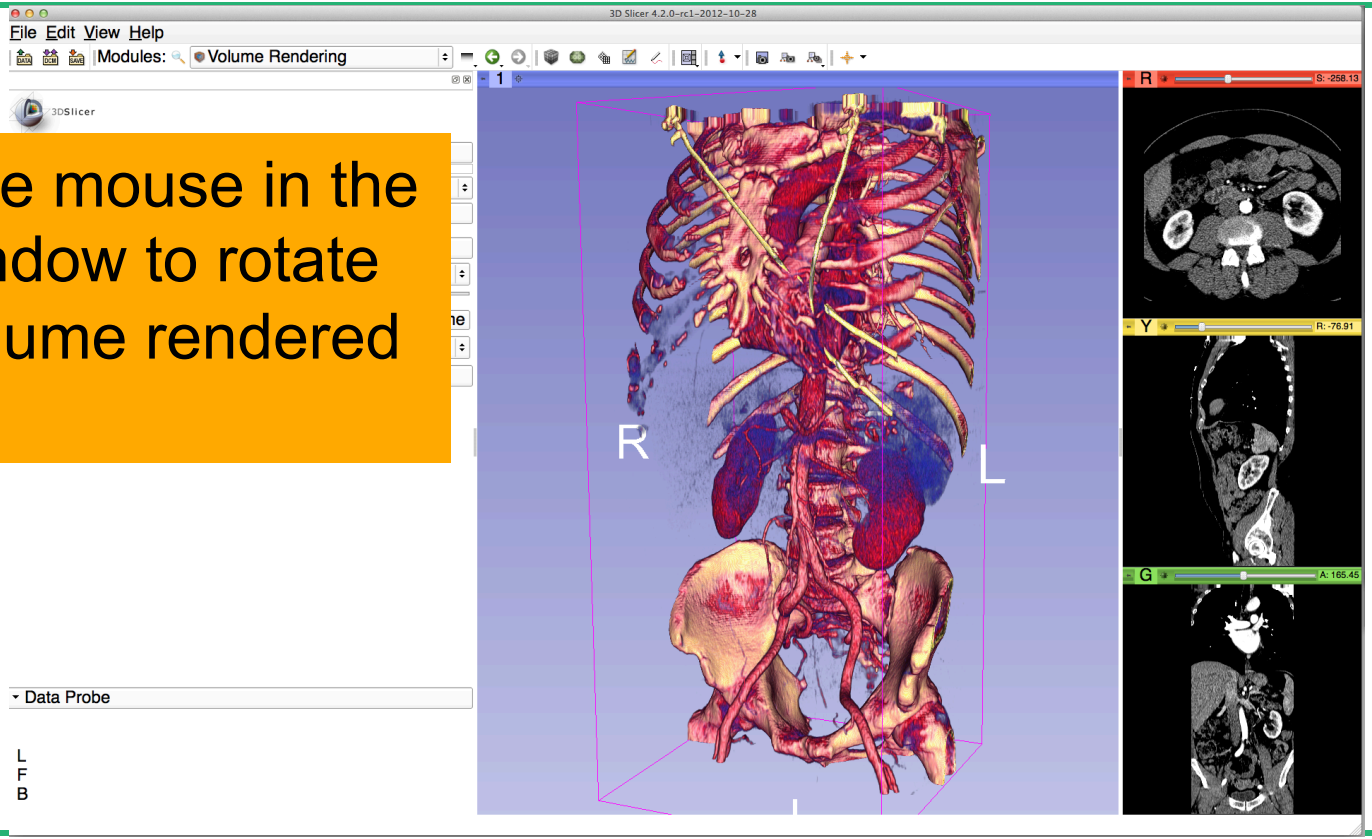
Volume Rendering

Use the mouse in the 3D window to rotate the volume rendered image



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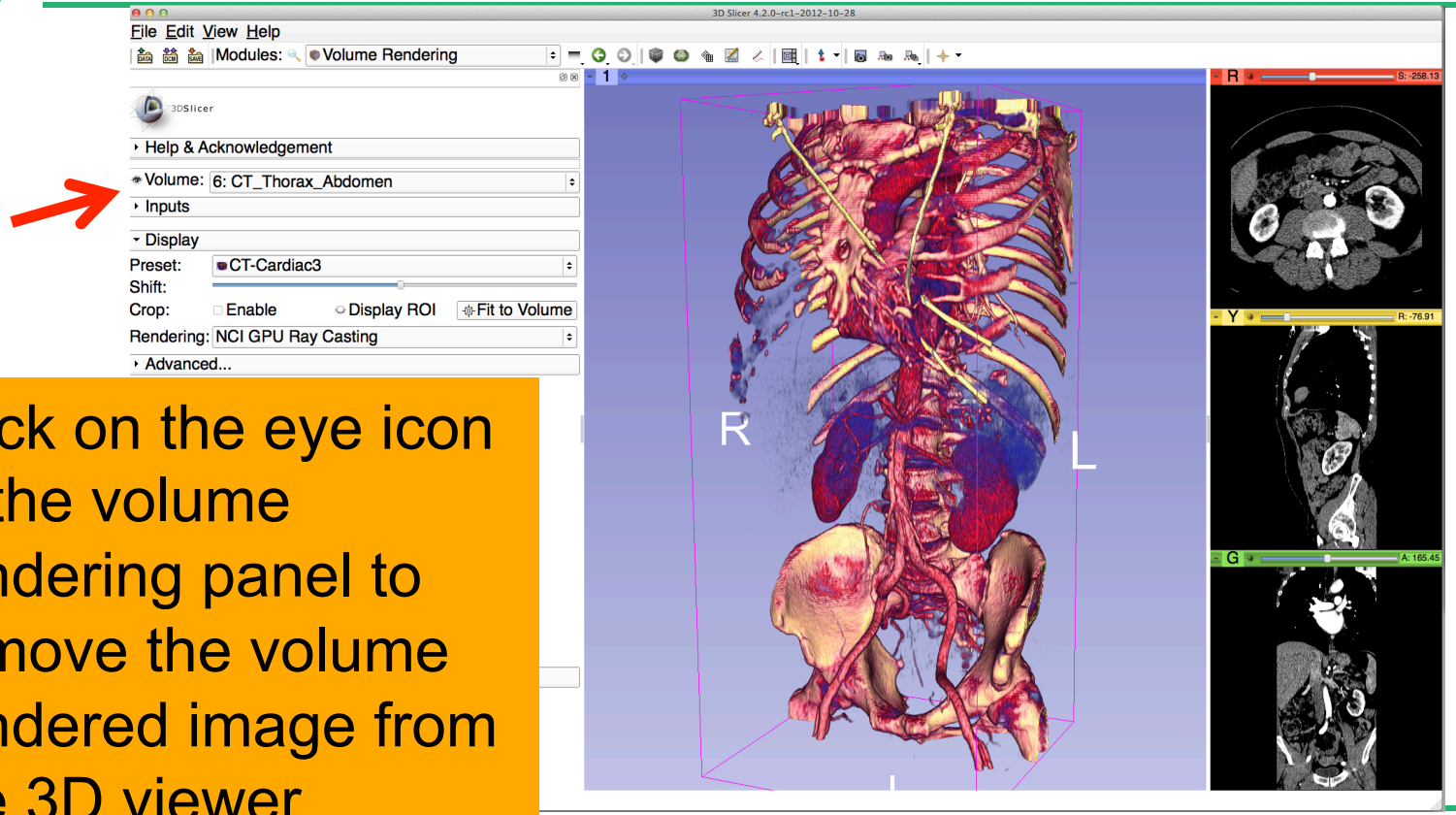
Volume Rendering



Click on the eye icon in the volume rendering panel to remove the volume rendered image from the 3D viewer

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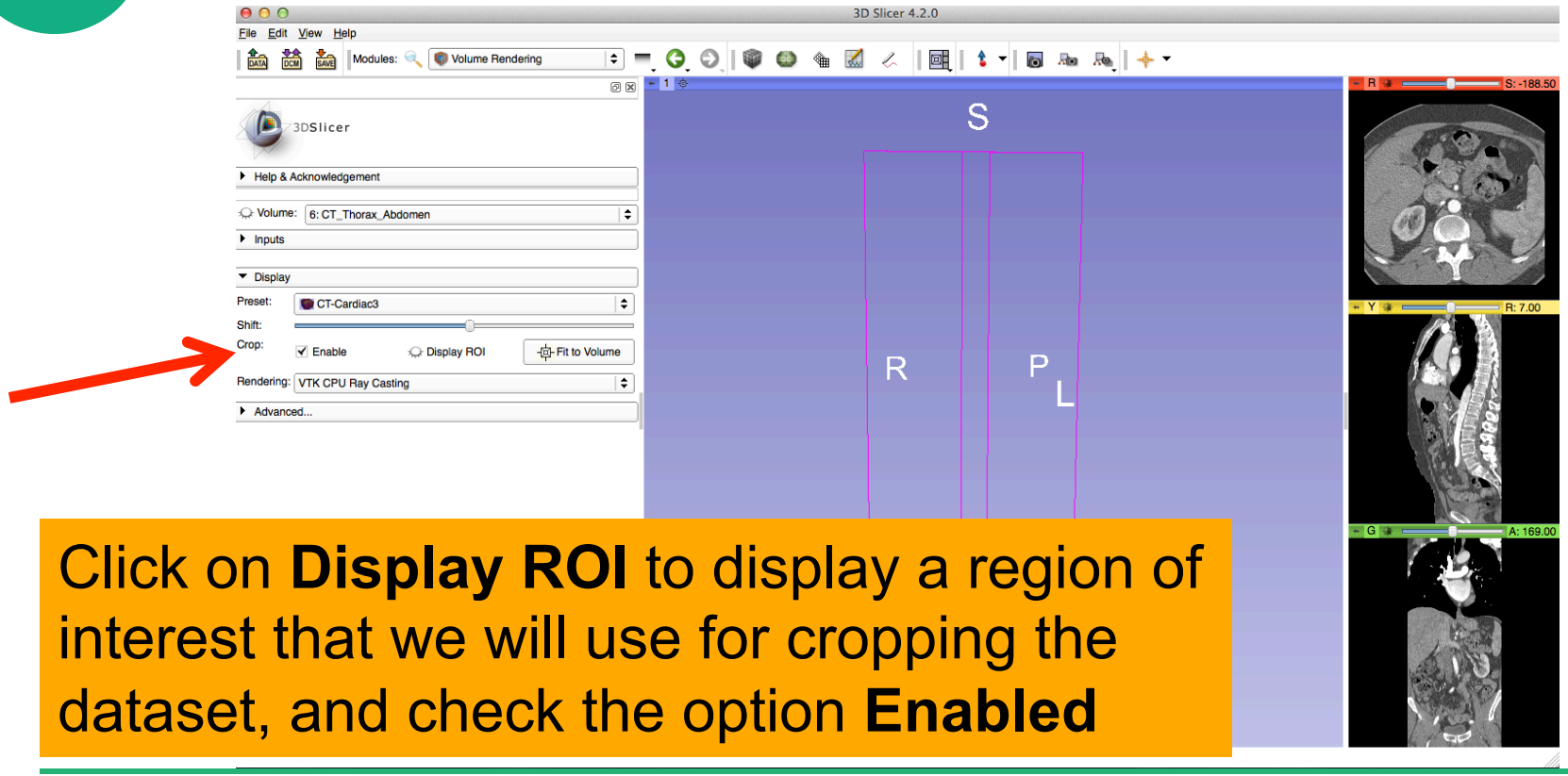
Volume Rendering



Click on **Display ROI** to display a region of interest that we will use for cropping the dataset, and check the option **Enabled**

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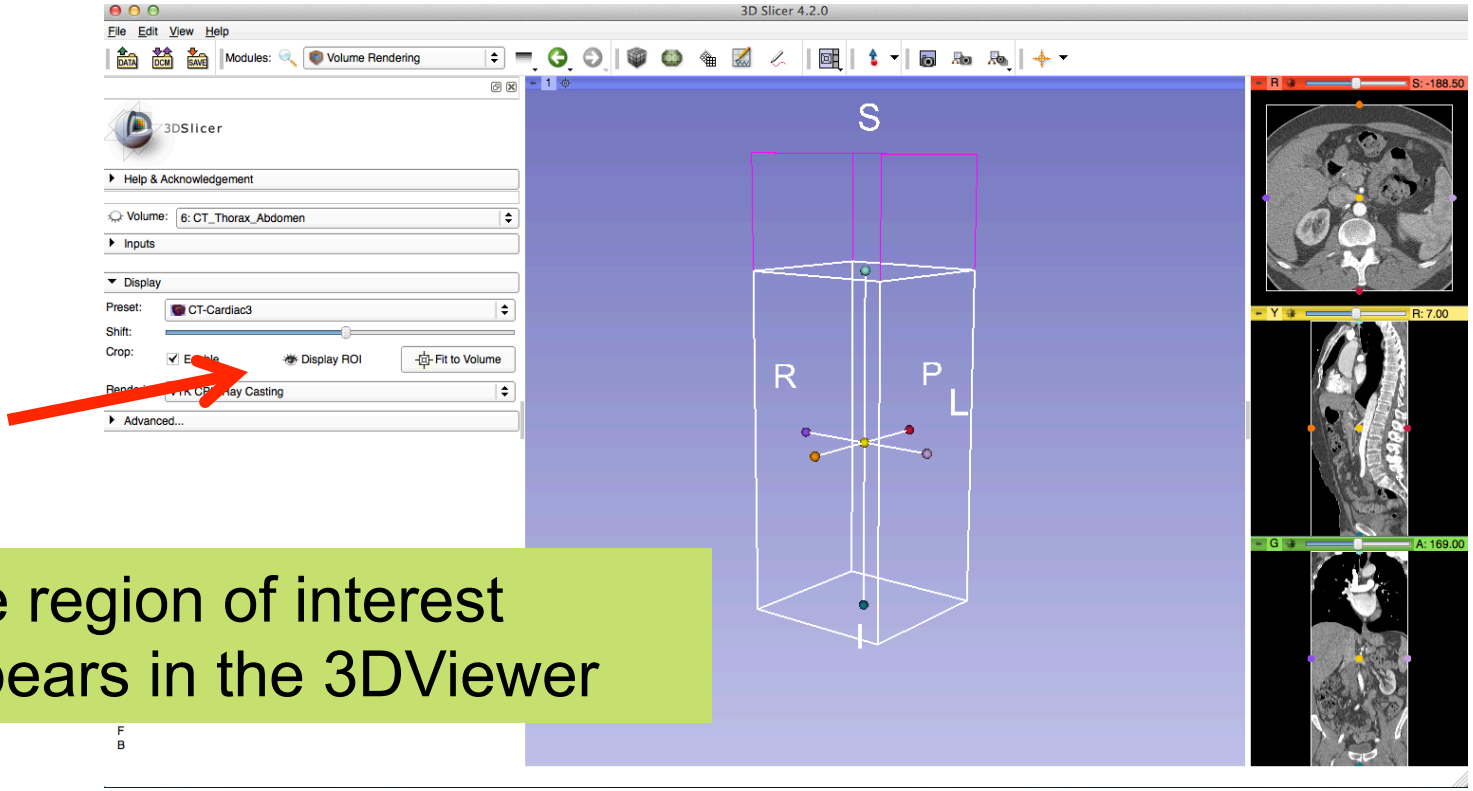
Volume Rendering



The region of interest appears in the 3DViewer

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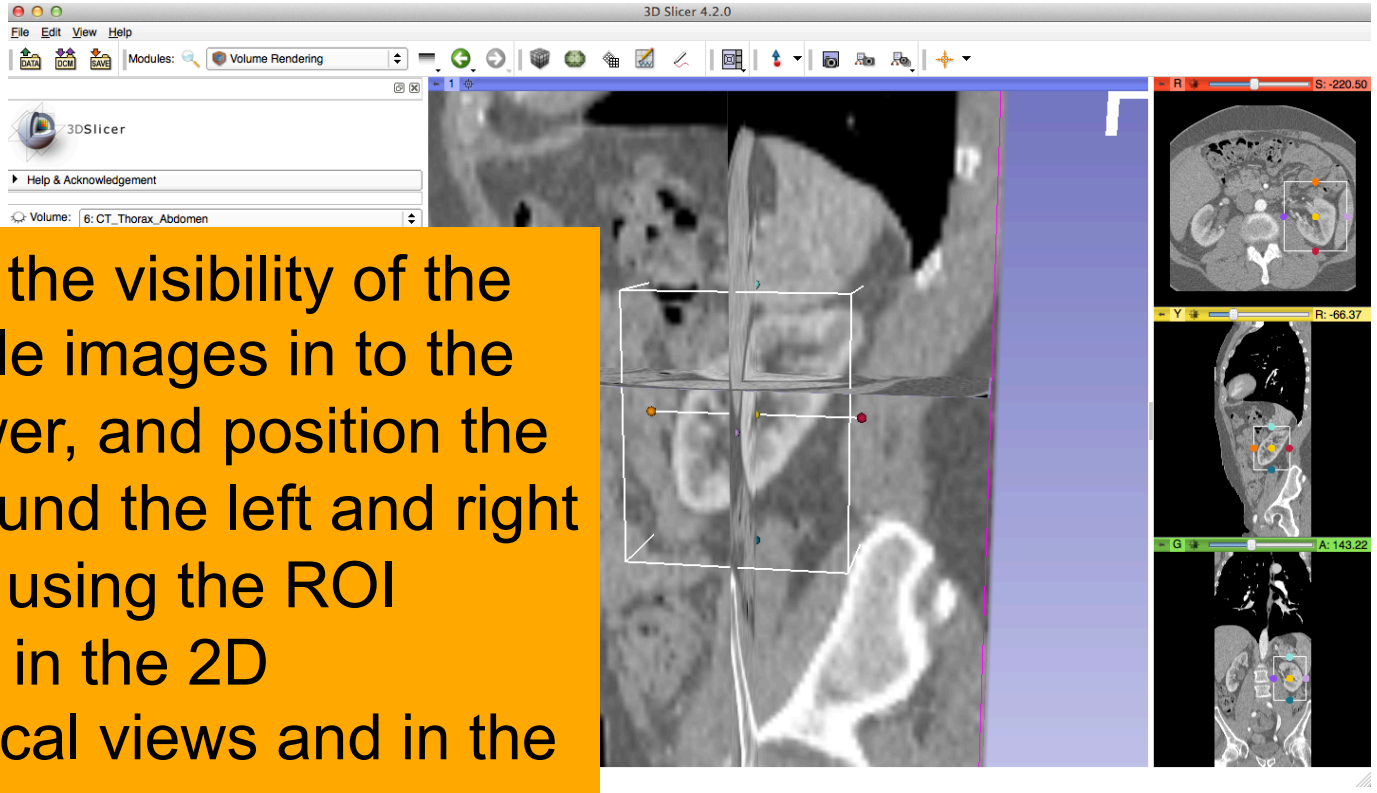
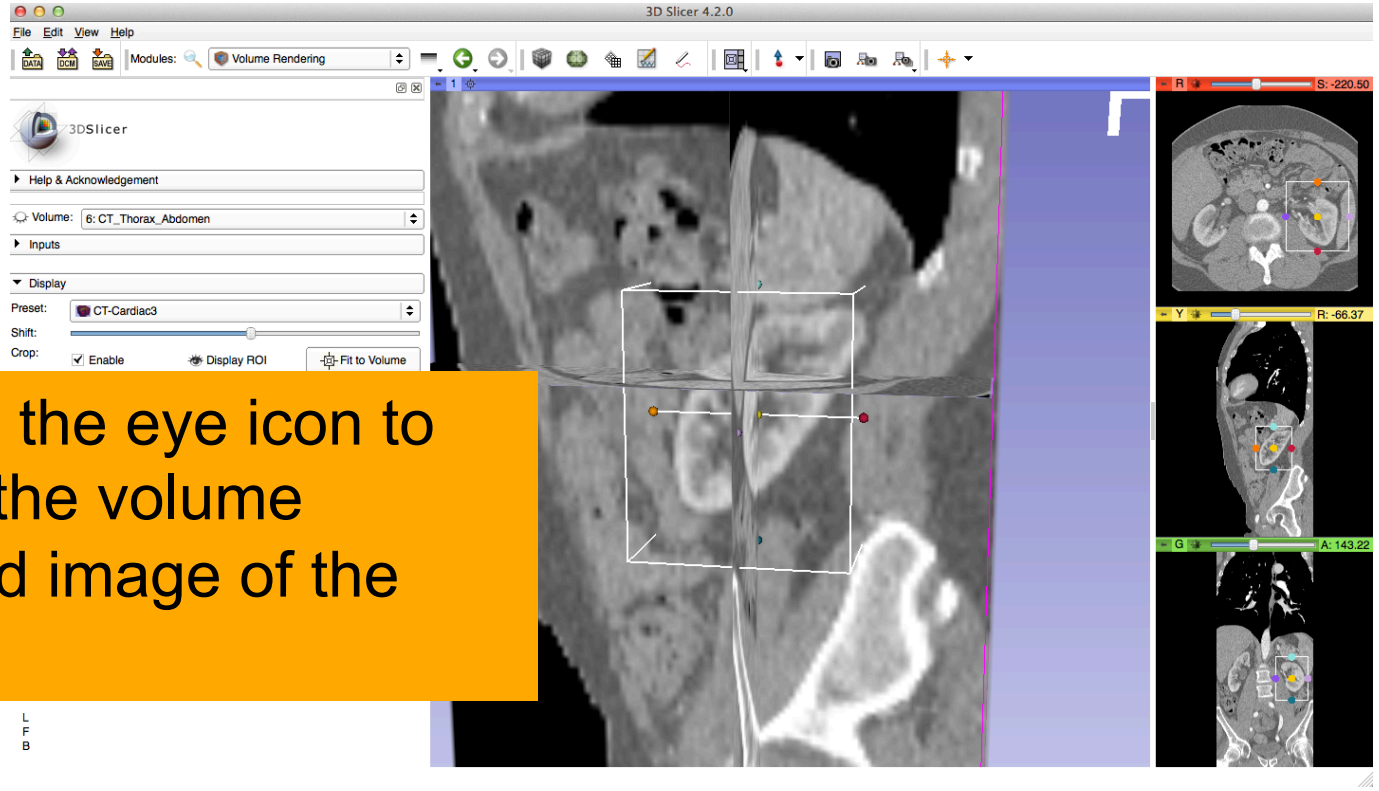
Volume Rendering



Turn on the visibility of the grayscale images in to the 3D Viewer, and position the ROI around the left and right kidneys using the ROI controls in the 2D anatomical views and in the 3D viewer

Volume Rendering



Click on the eye icon to display the volume rendered image of the kidney

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Volume Rendering

Slicer displays the volume rendered image of the left kidney

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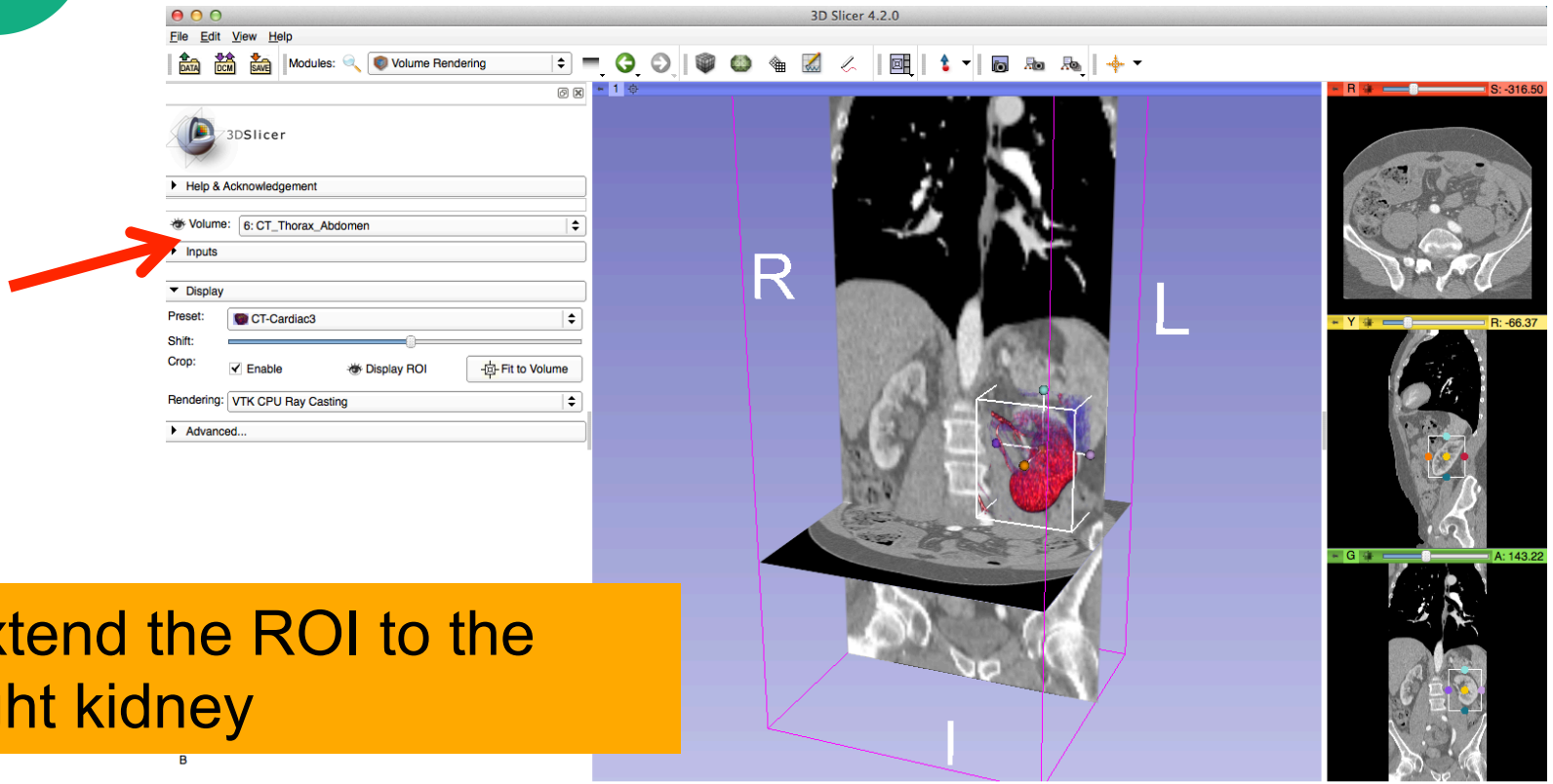
Volume Rendering



Extend the ROI to the right kidney

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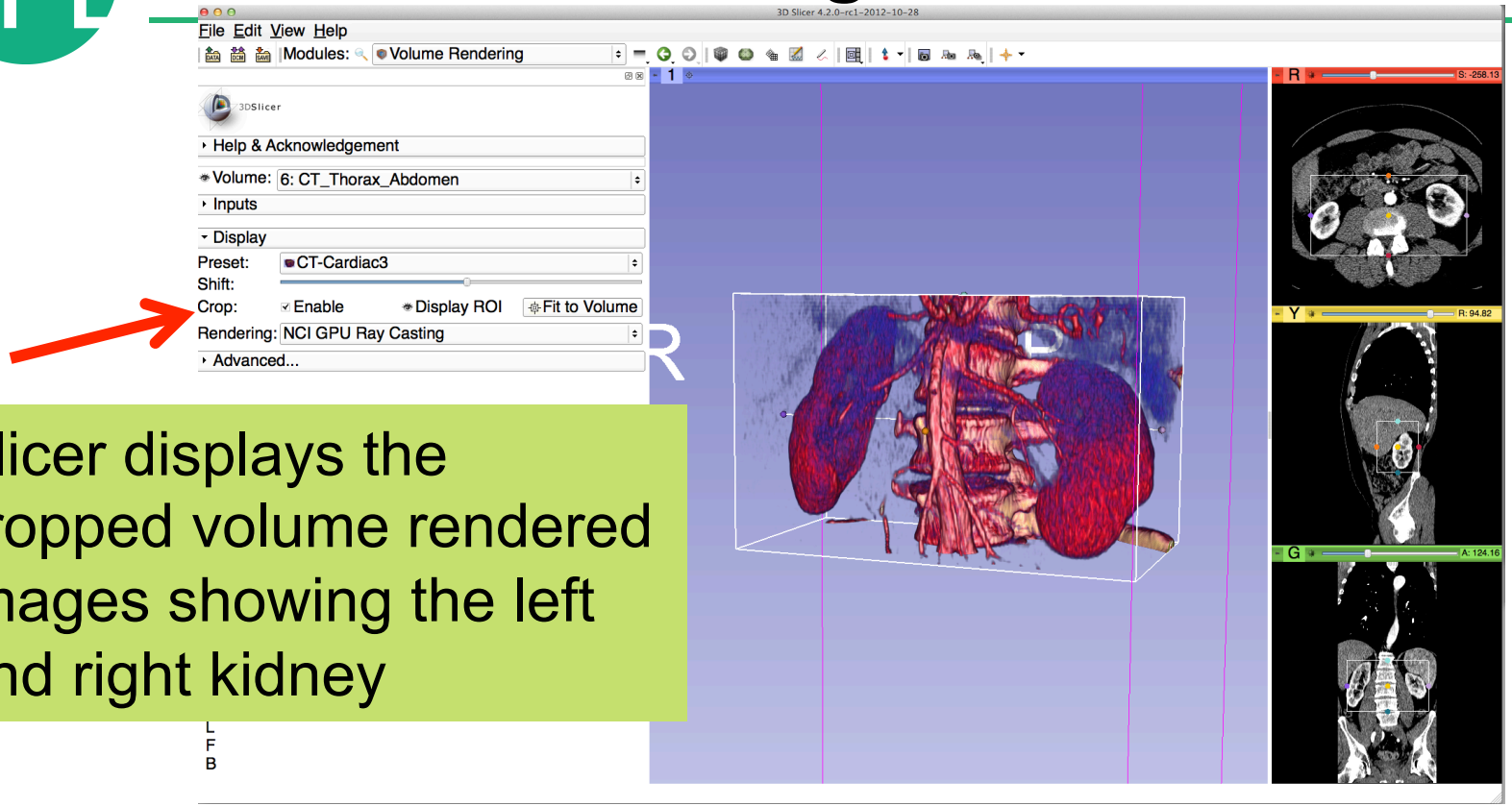
Volume Rendering



Slicer displays the cropped volume rendered images showing the left and right kidney

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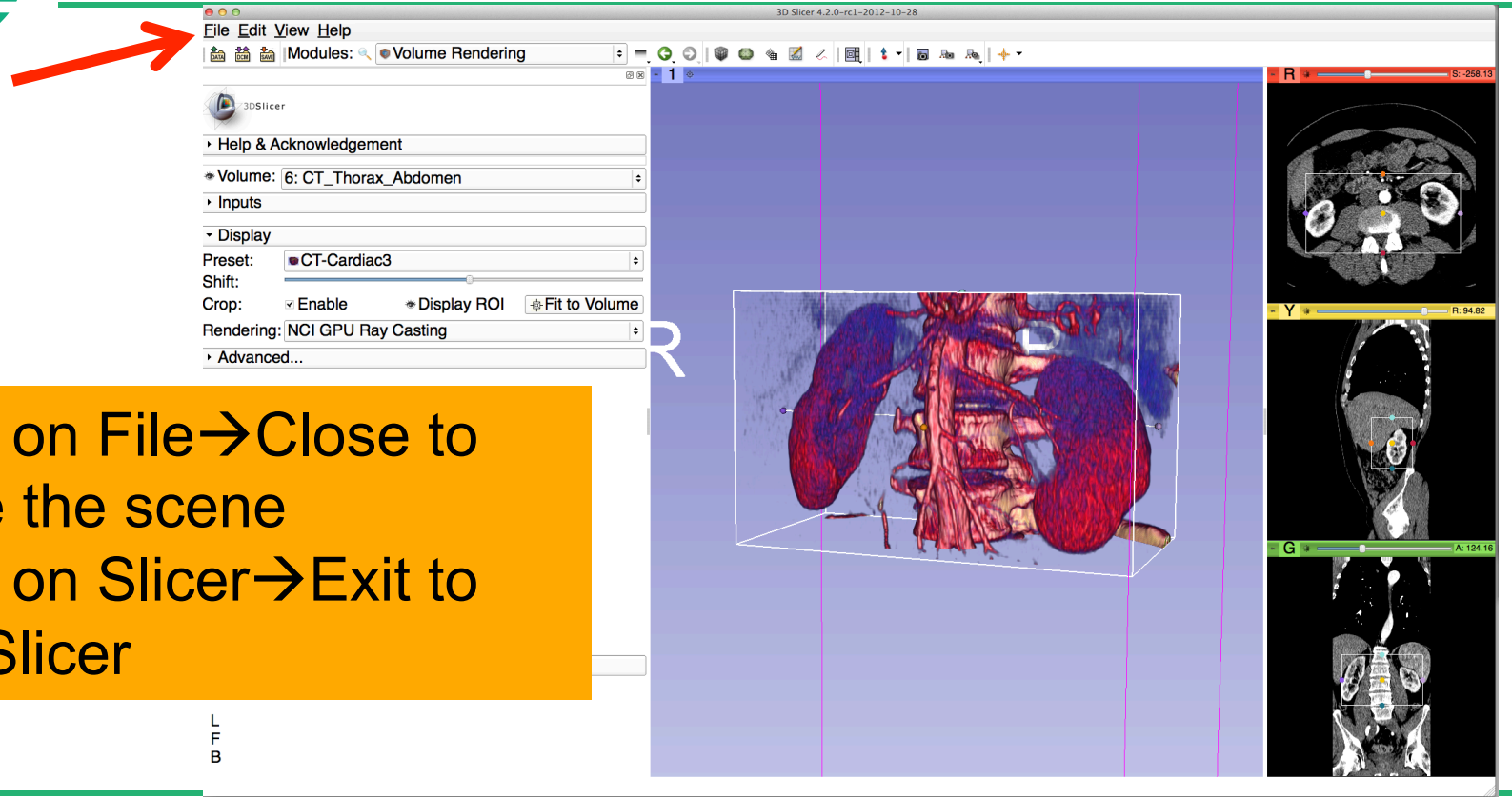
Volume Rendering



Click on File→Close to close the scene
Click on Slicer→Exit to quit Slicer

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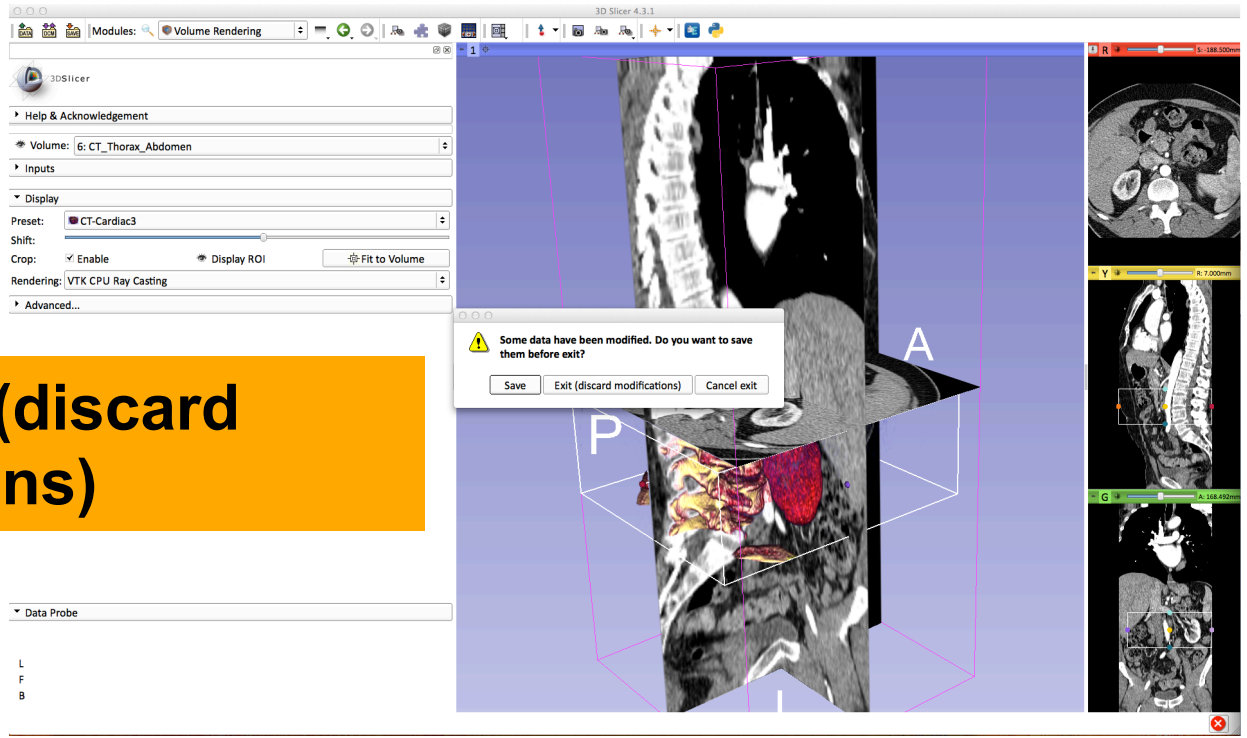
Volume Rendering



Select **Exit (discard modifications)**

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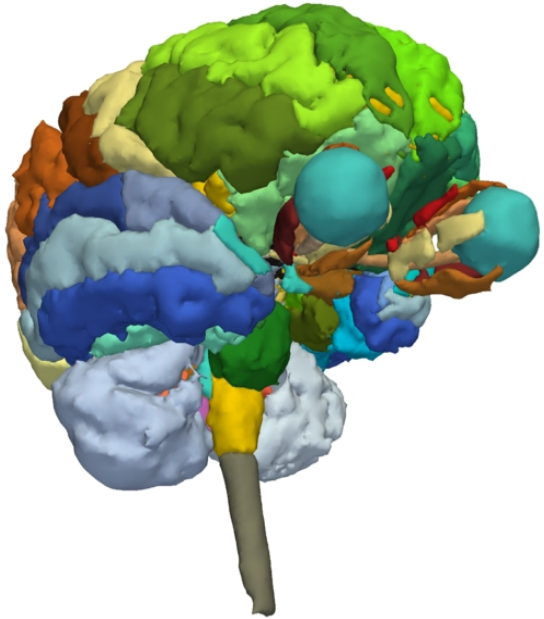

3D visualization of surface models of the brain

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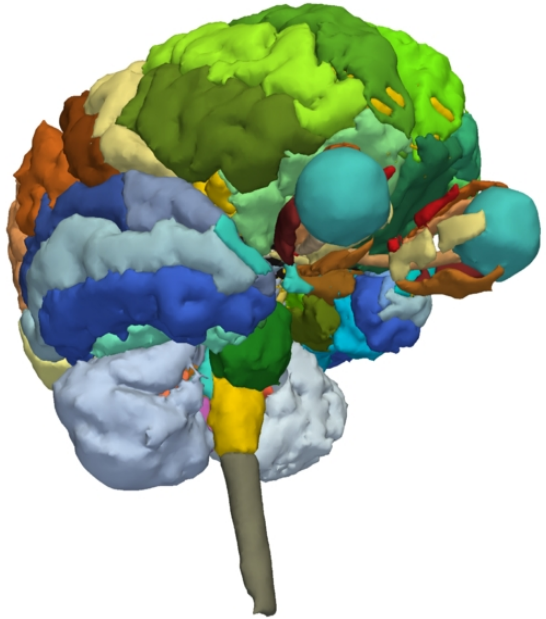
3D Data Loading and Visualization



- This tutorial is a short introduction to the advanced **3D visualization capabilities Slicer**
- The Slicer4 Minute dataset is composed of an MR scan of the brain and 3D surface reconstructions of anatomical structures.
- The data are part of the SPL-PNL Brain Atlas developed by Talos, Jakab, Kikinis *et al.* The atlas is available at:

http://www.spl.harvard.edu/publications/item/view/2037

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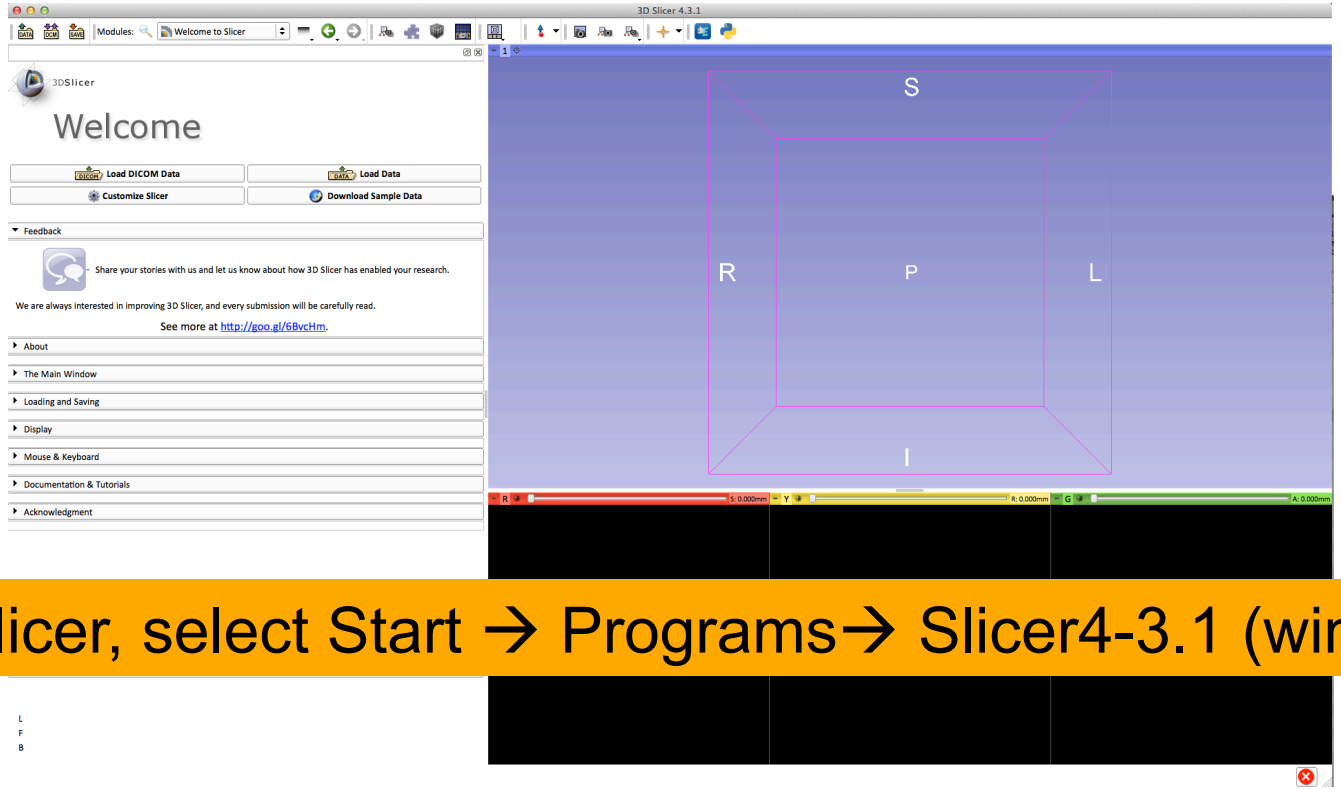
Welcome to Slicer4



To start Slicer, select Start → Programs→ Slicer4-3.1 (win64)

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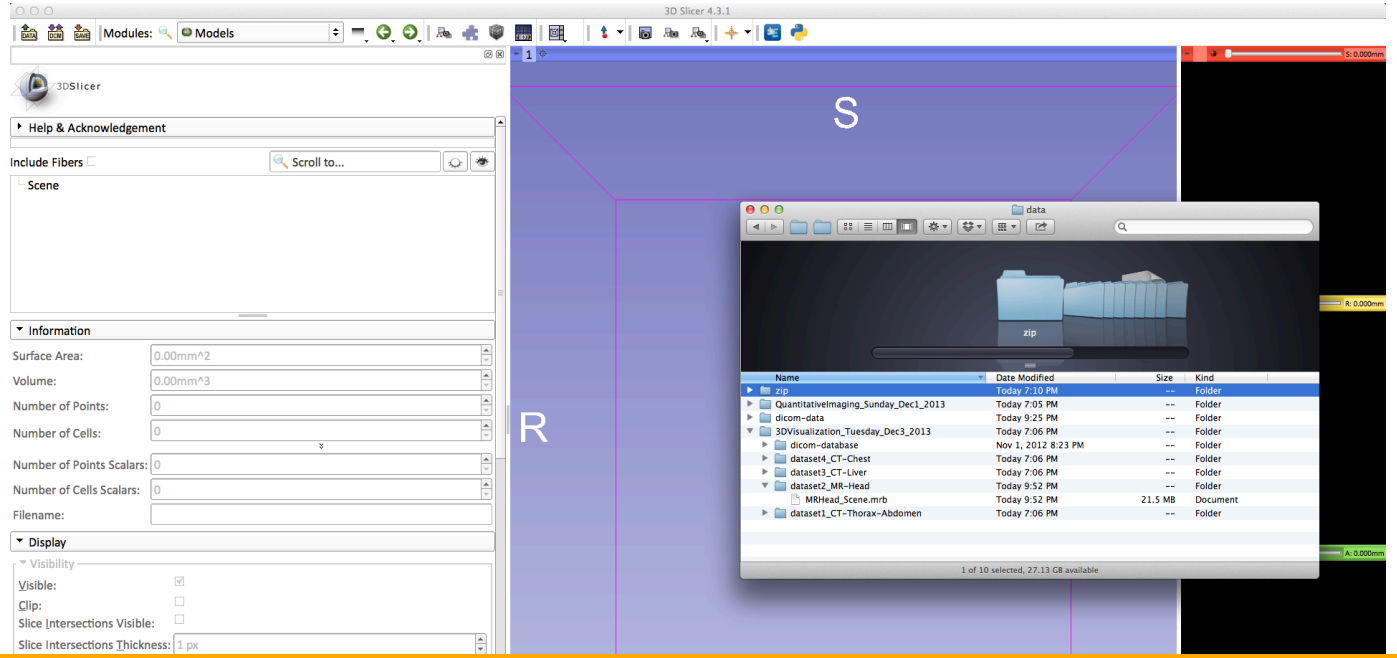
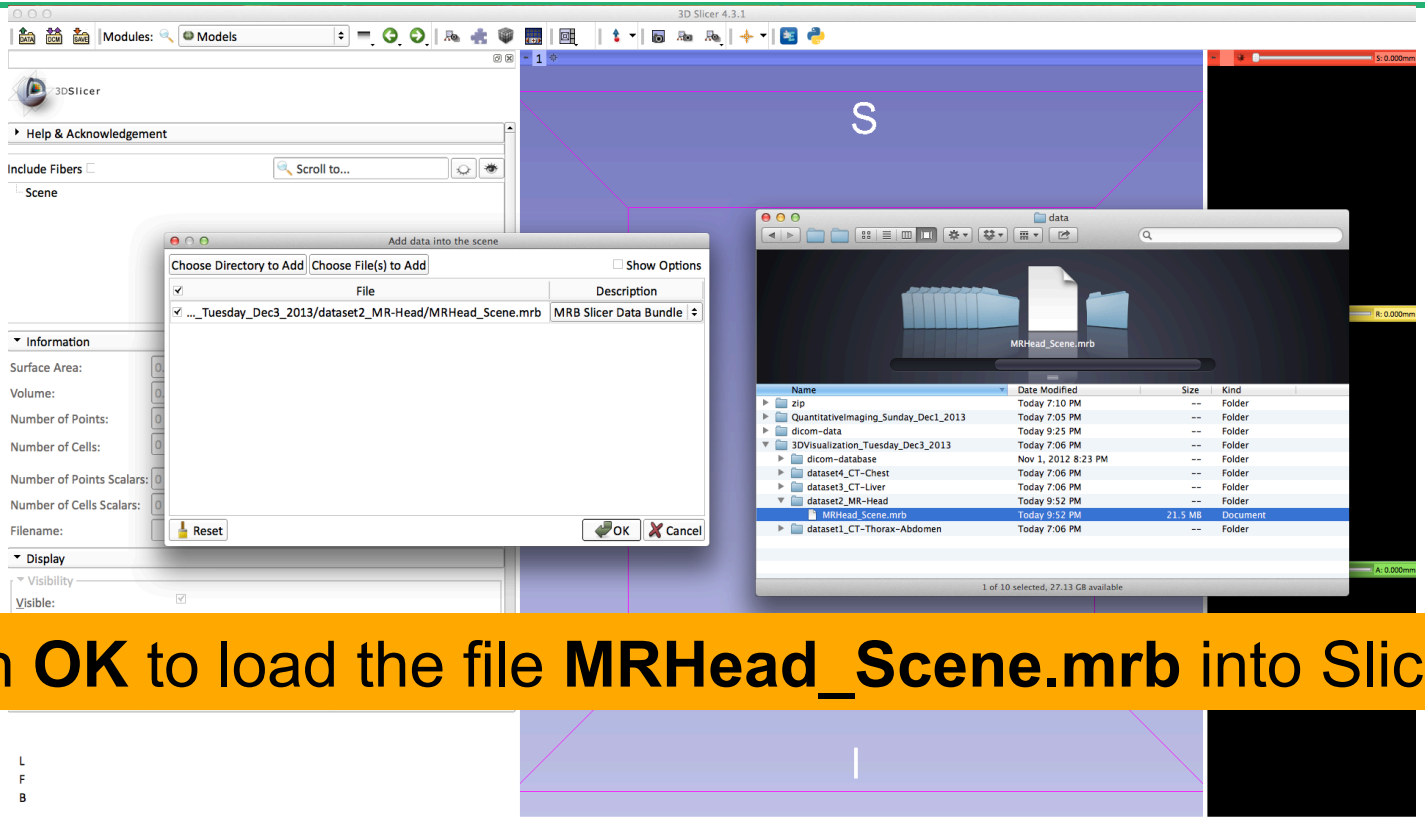
Slicer4 Minute Tutorial: Viewing the Scene



Open the directory **dataset2_Head** located in **C:/3DSlicerData_RSNA2013/3DVisualizationDICOM_Tuesday_Dec3**
Drag and drop the file **Head_Scene.mrb** into Slicer

Slicer4 Minute Tutorial: Viewing the Scene



Click on **OK** to load the file **MRHead_Scene.mrb** into Slicer

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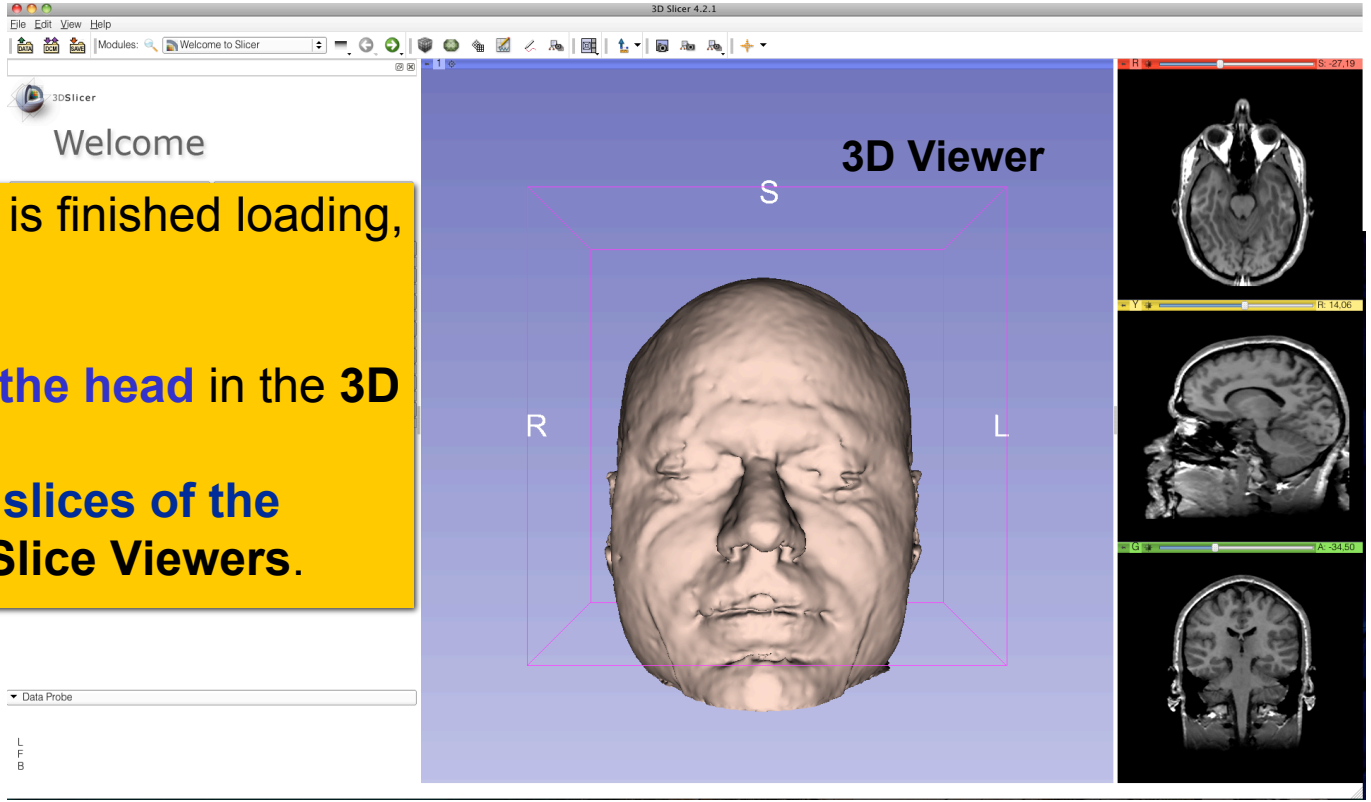
Slicer4 Minute Tutorial: Viewing the Scene

When the scene is finished loading, Slicer displays:

- a **3D model of the head** in the **3D Viewer**, and
- anatomical **MR slices of the brain** in the **2D Slice Viewers**.



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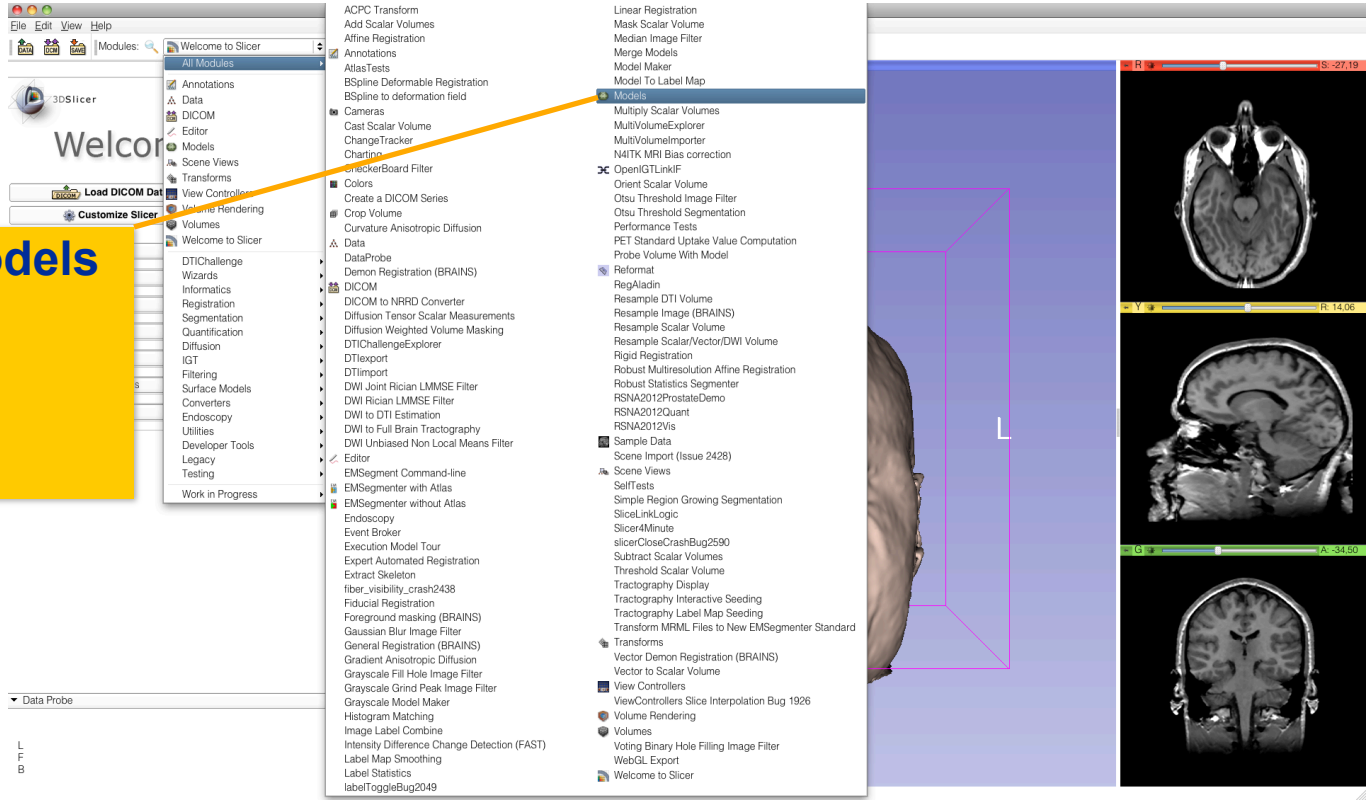
Slicer4 Minute Tutorial: Exploring Slicer's functionality

To access the **Models module**, browse through the list of modules.



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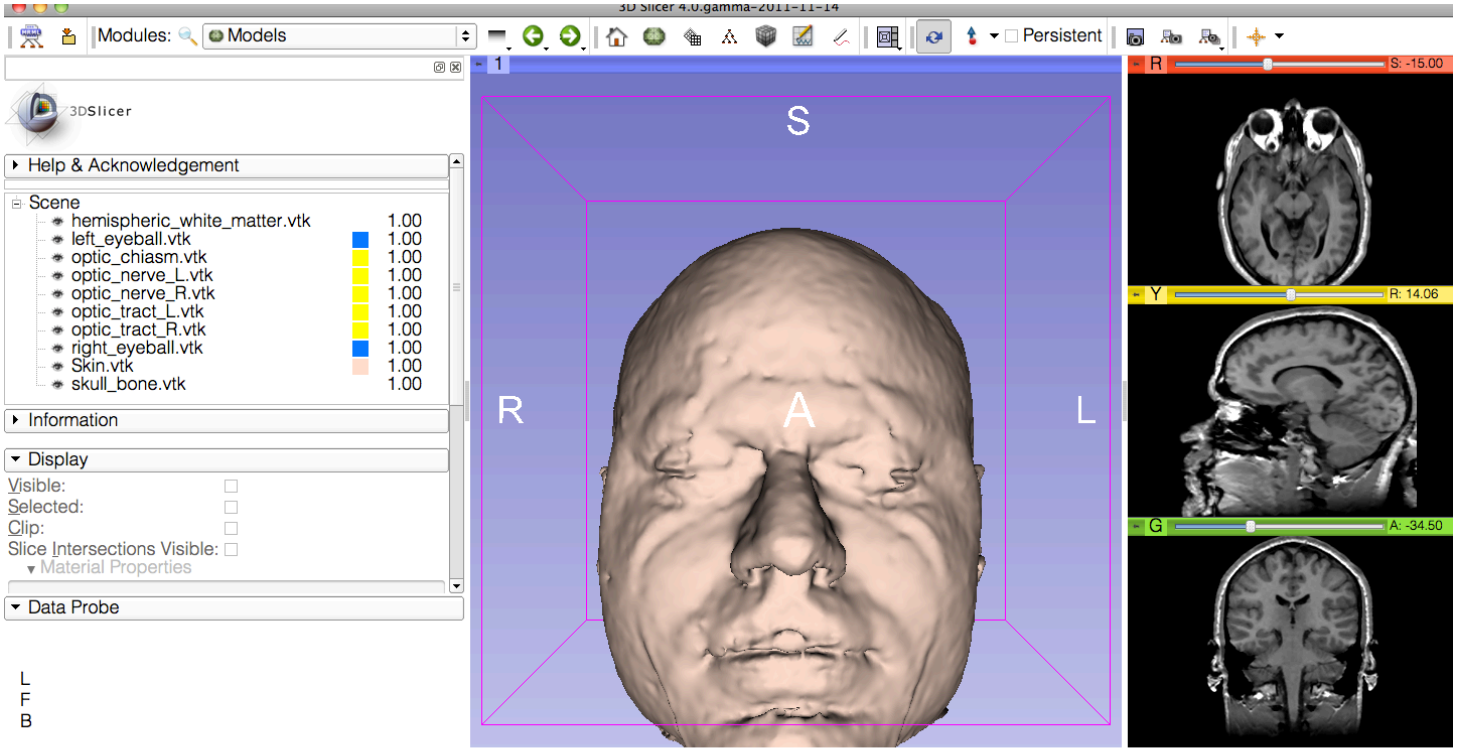
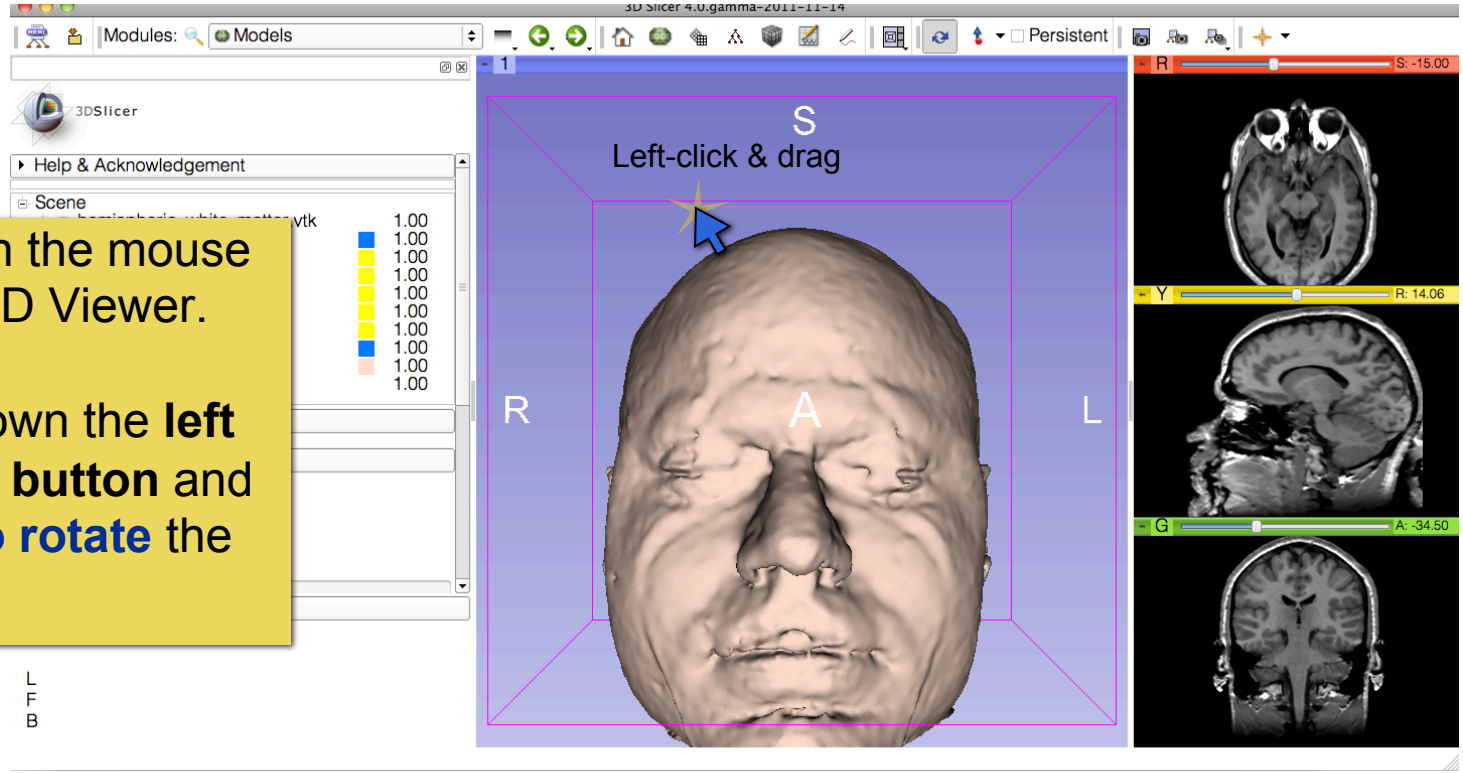
Slicer4 Minute Tutorial: Switching to the Models Module



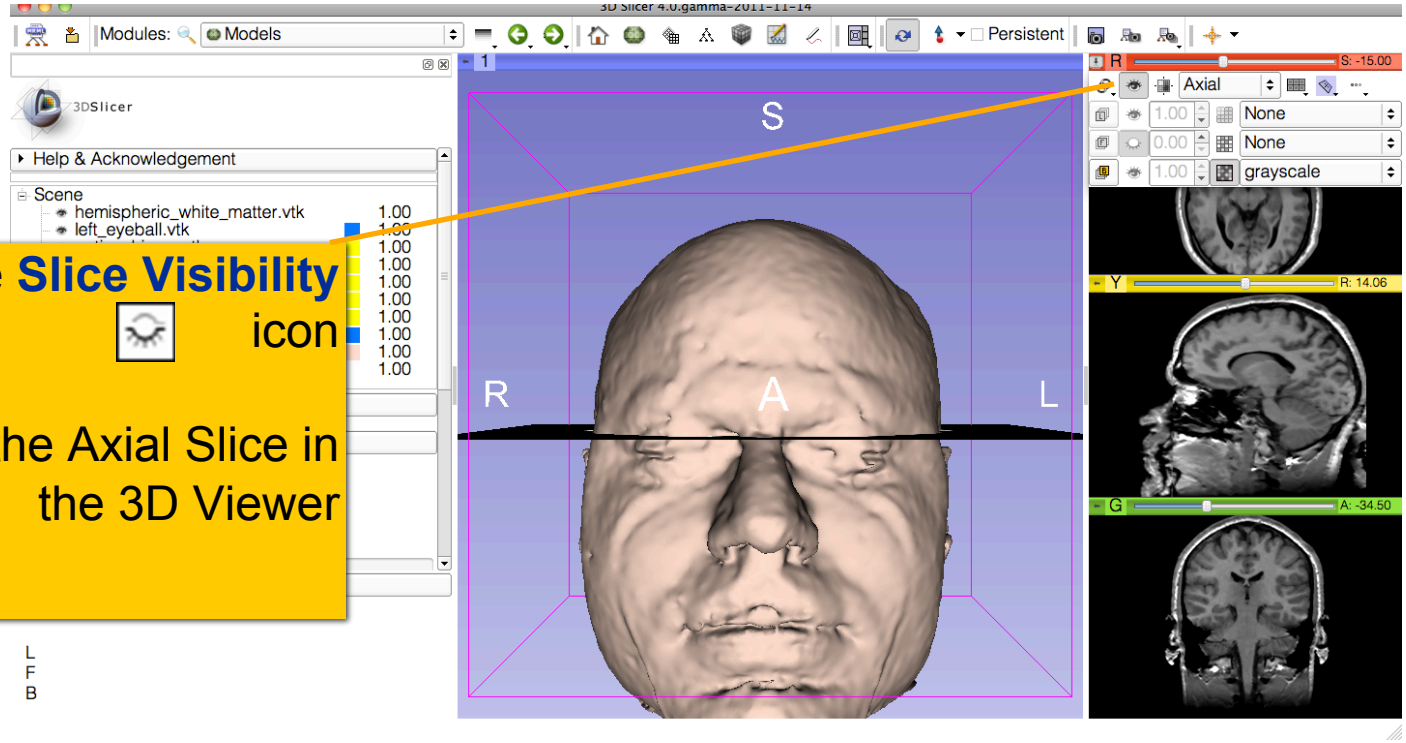
Slicer4 Minute Tutorial: Basic 3D Interaction



Position the mouse in the 3D Viewer.

Hold down the **left mouse button** and **drag to rotate** the model.

Slicer4 Minute Tutorial: Viewing Slices in the 3D Viewer



Click on the **Slice Visibility** icon

to display the Axial Slice in the 3D Viewer

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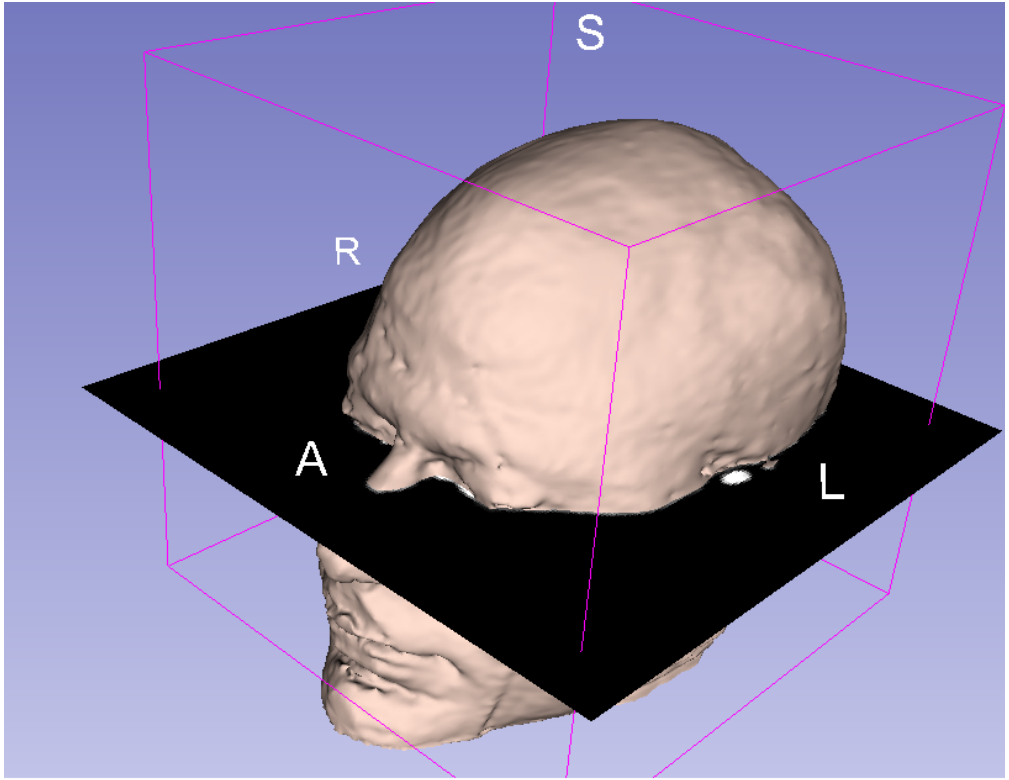
Slicer4 Minute Tutorial: 3D Visualization

Slicer adds a view of the **Axial slice** in the 3D View.



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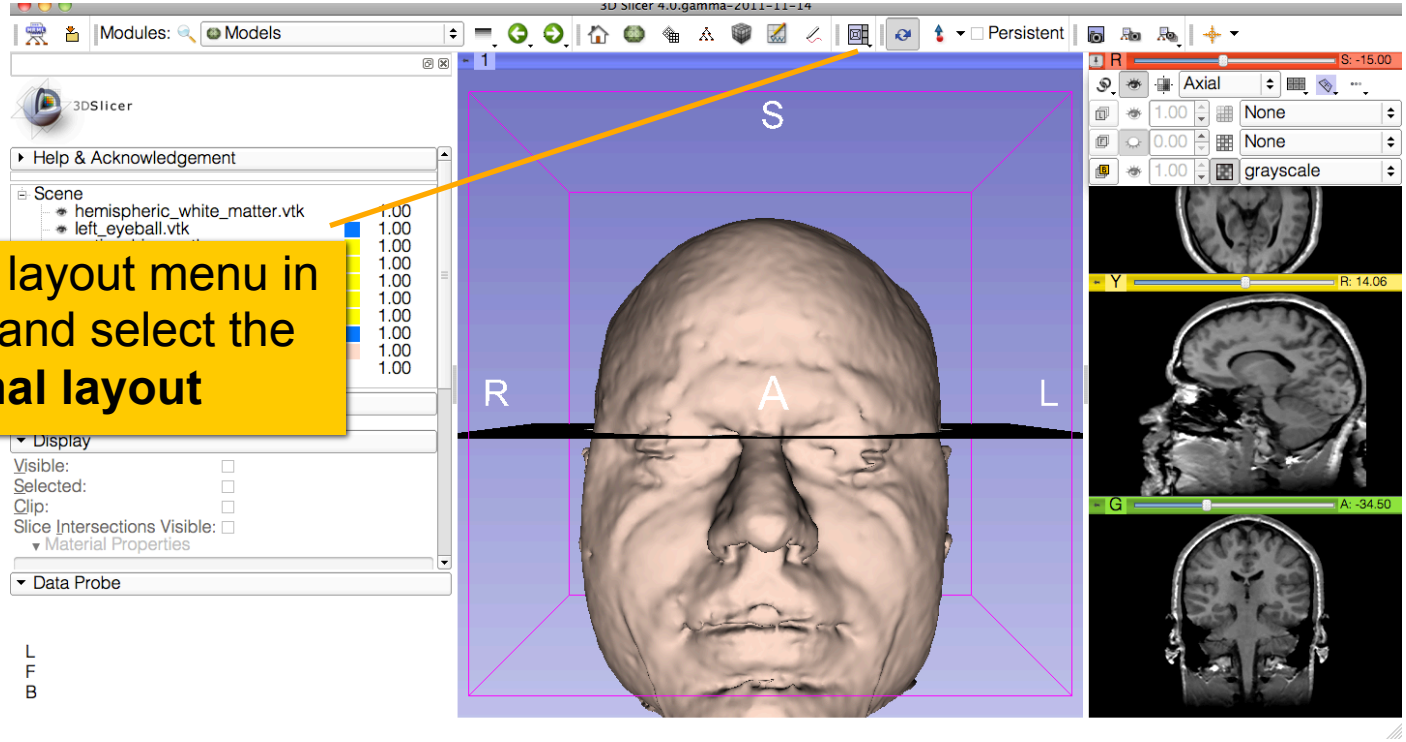
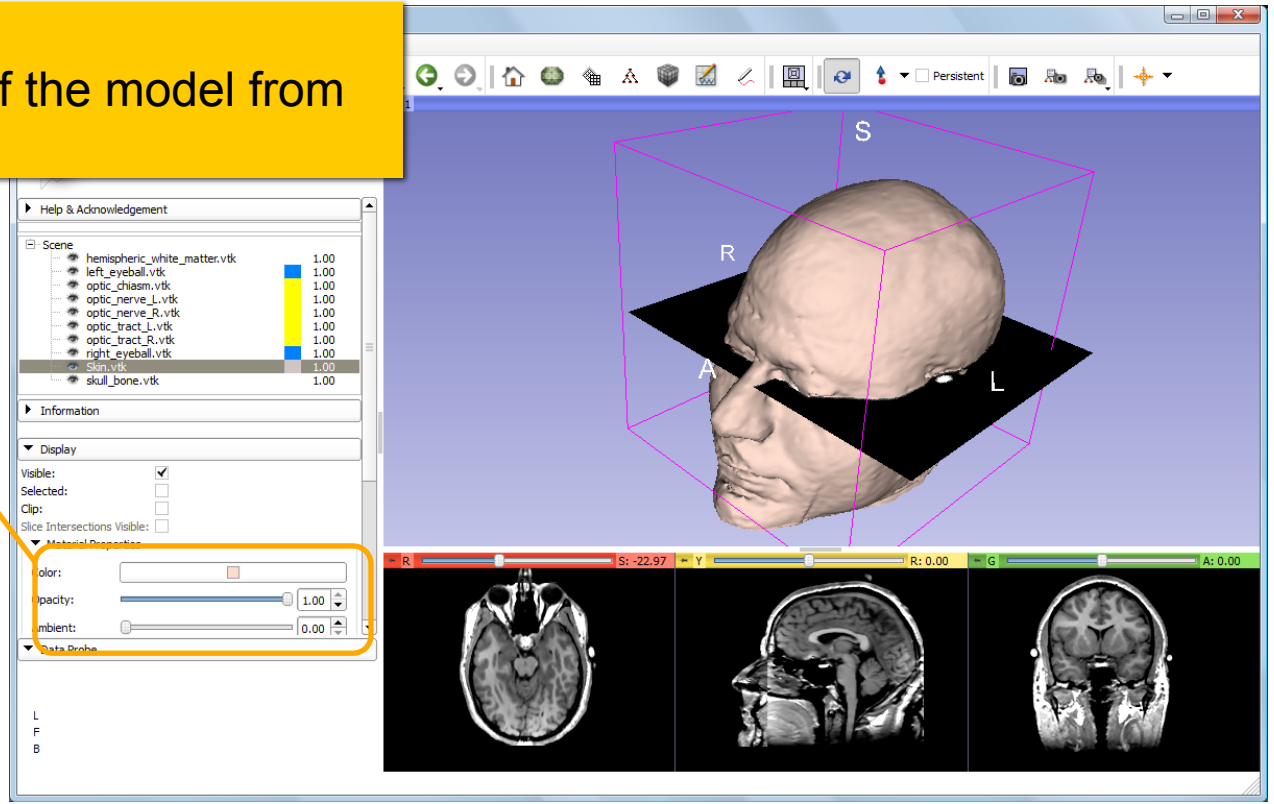
Slicer4 Minute Tutorial: Viewing Slices in the 3D Viewer



Click on the layout menu in the toolbar, and select the **Conventional layout**

Slicer4 Minute Tutorial: 3D Visualization

Select the **Skin.vtk**
Change the opacity of the model from **1.0** to **0.0**.



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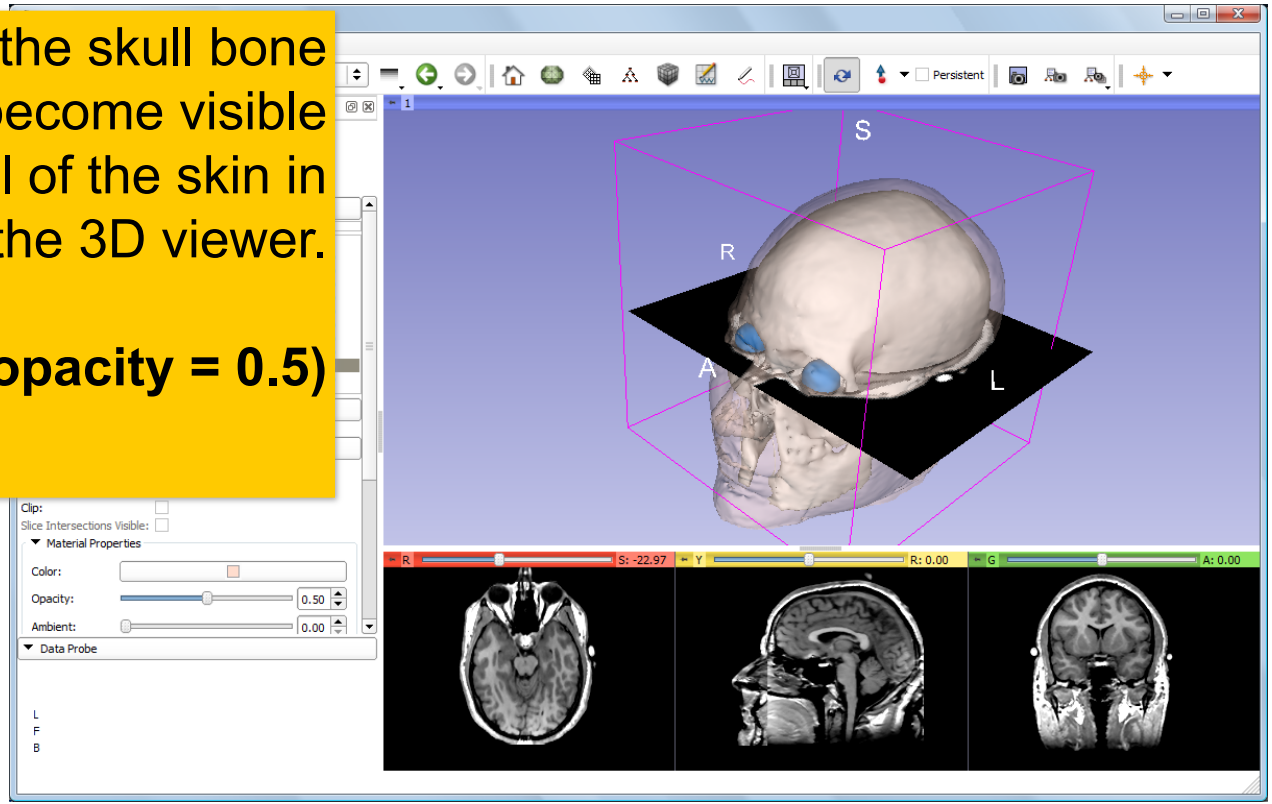
Slicer4 Minute Tutorial: 3D Visualization

The model of the skull bone and eyeballs become visible through the model of the skin in the 3D viewer.

(skin model opacity = 0.5)



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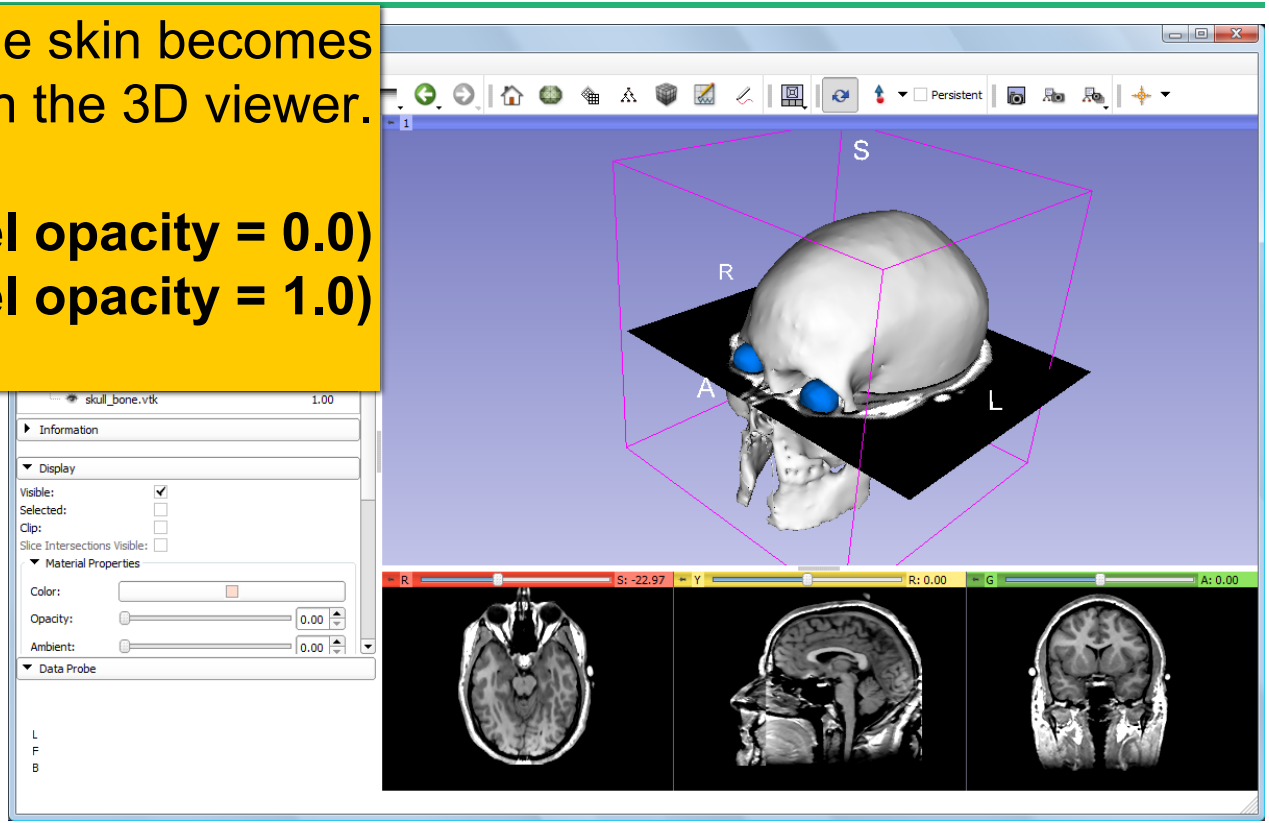
Slicer4 Minute Tutorial: 3D Visualization

The model of the skin becomes invisible in the 3D viewer.

(skin model opacity = 0.0)
(skull model opacity = 1.0)



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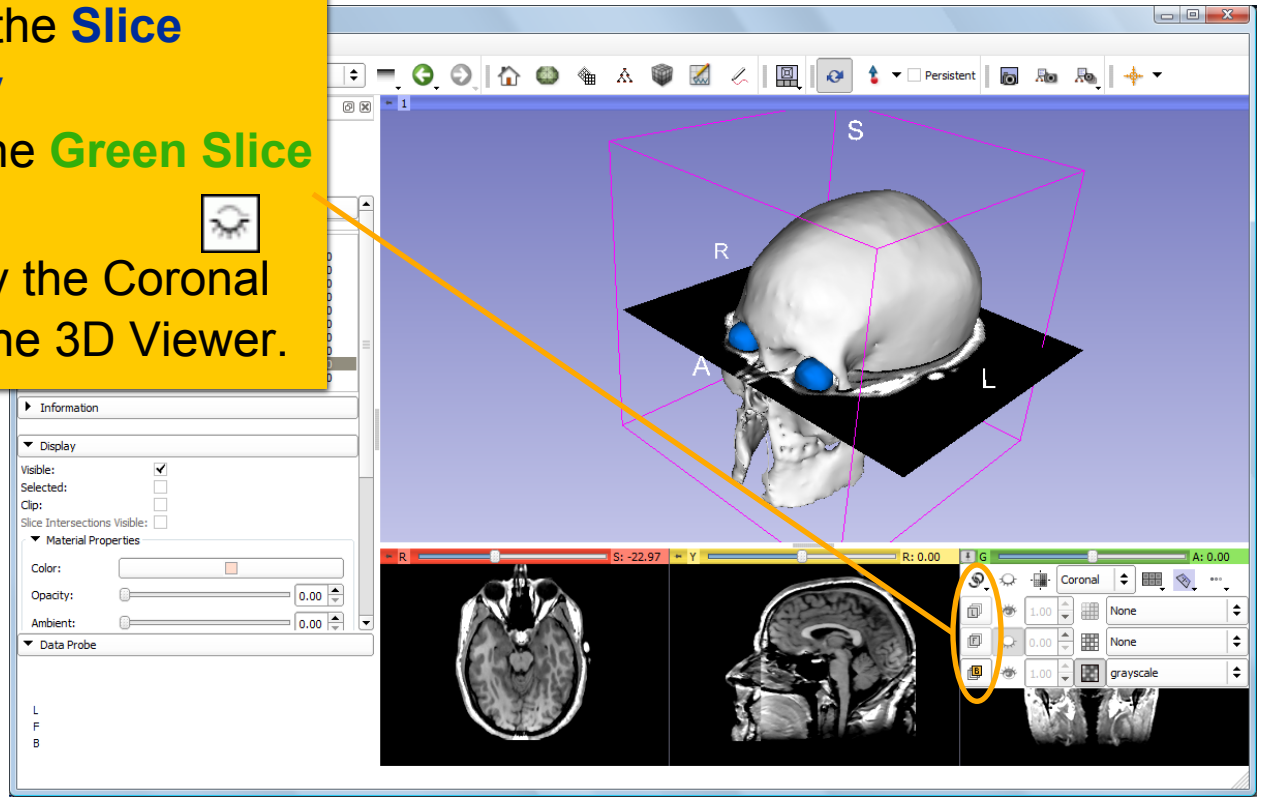
Slicer4 Minute Tutorial: 3D Visualization

Click on the **Slice Visibility icon** in the **Green Slice Viewer** to display the Coronal Slice in the 3D Viewer.



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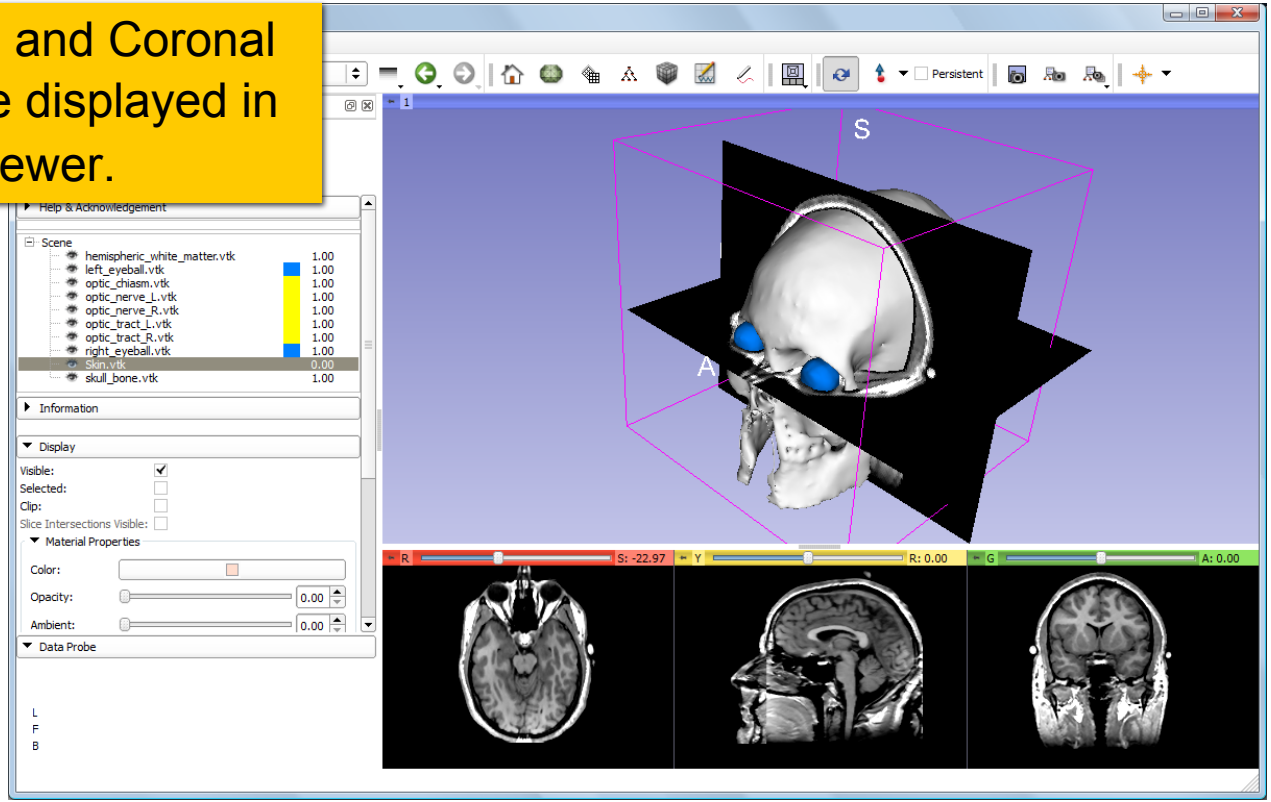
Slicer4 Minute Tutorial: 3D Visualization

The Axial and Coronal Slices are displayed in the 3D Viewer.



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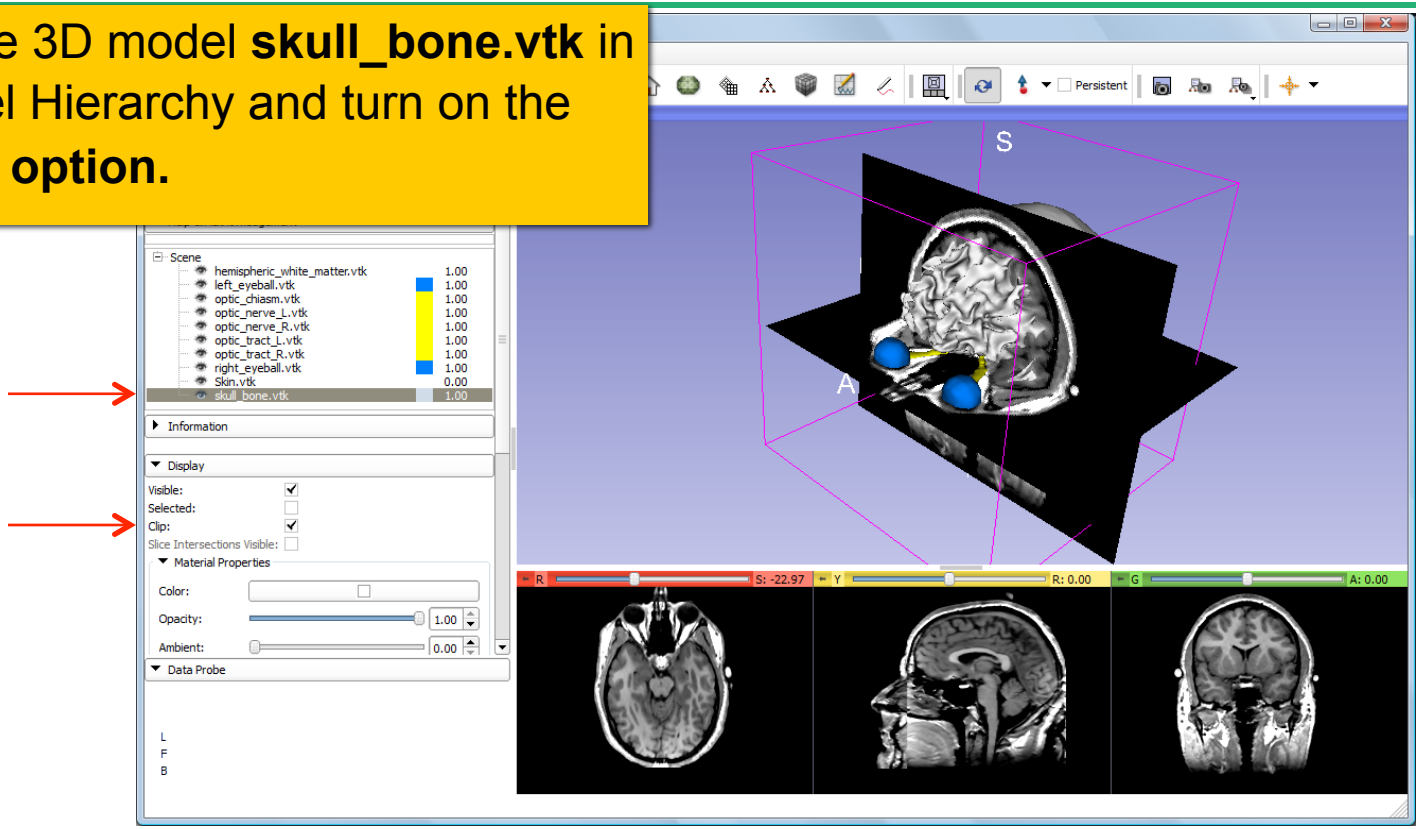
Slicer4 Minute Tutorial: 3D Visualization

Select the 3D model **skull_bone.vtk** in the Model Hierarchy and turn on the **Clipping option.**



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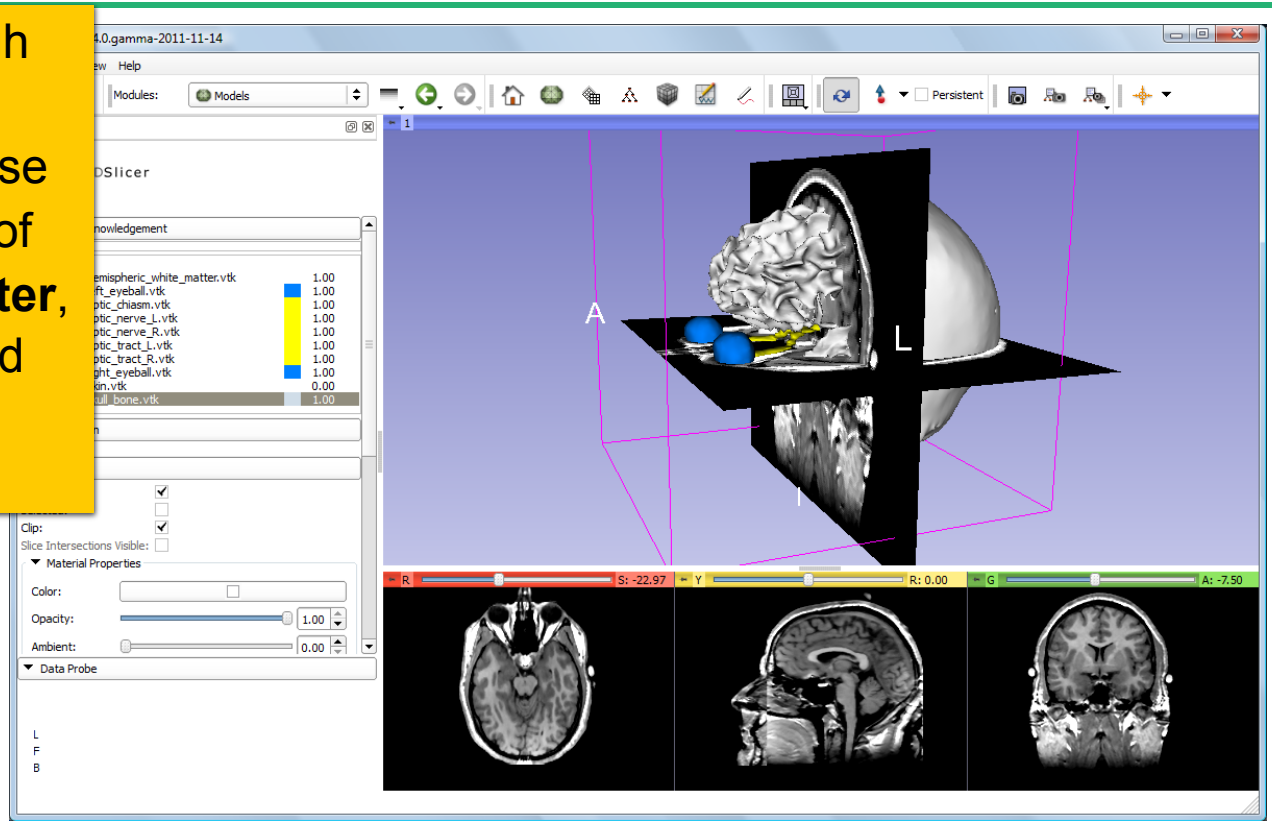
Slicer4 Minute Tutorial: 3D Visualization

Browse through the **coronal slices** to expose the 3D model of the **white matter**, and the left and right **optic nerves**.



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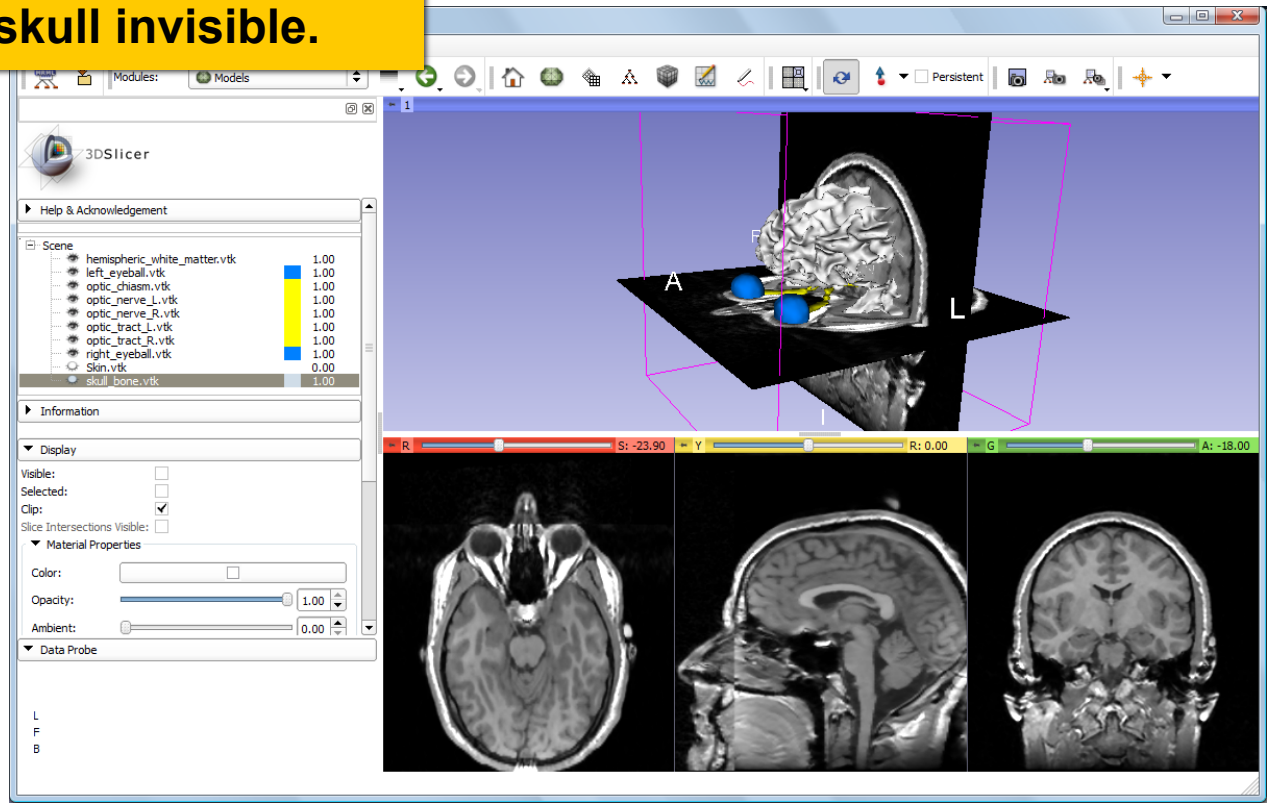
Slicer4 Minute Tutorial: 3D Visualization

Now **make the skull invisible.**



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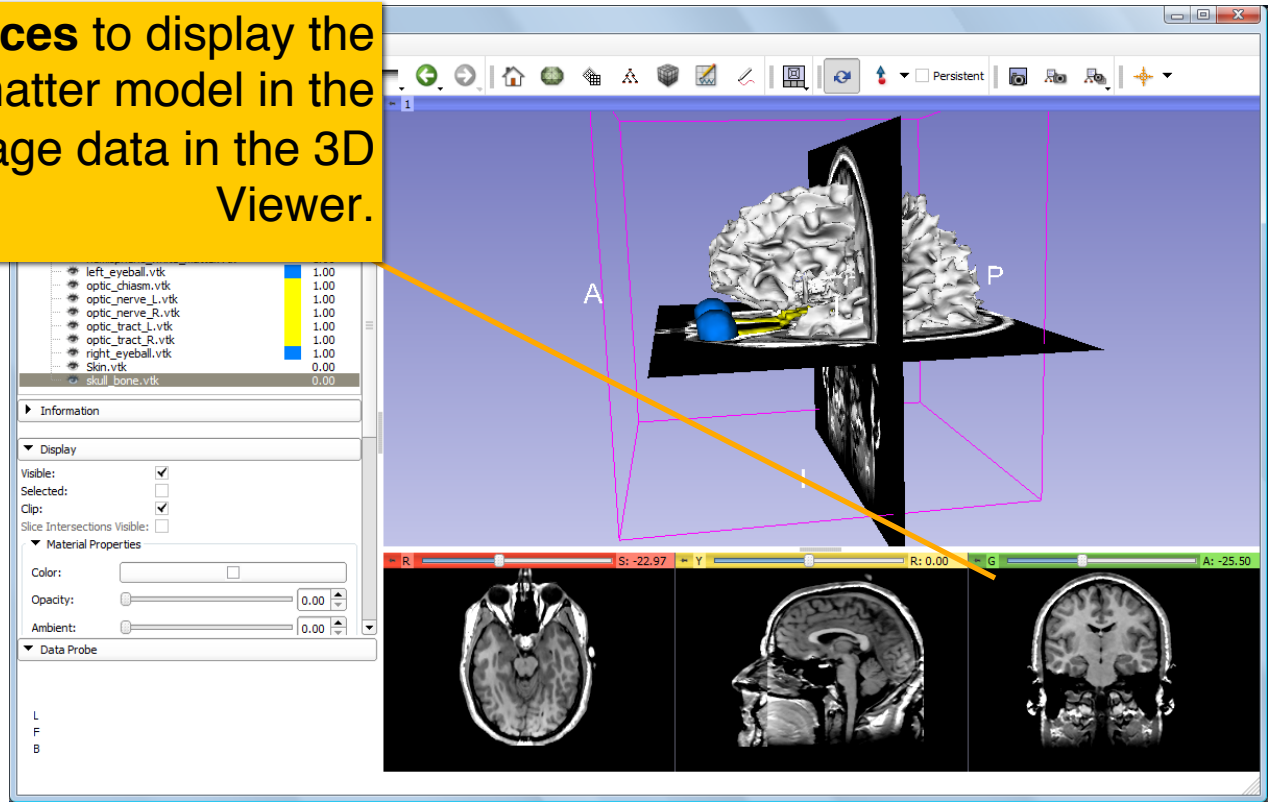
Slicer4 Minute Tutorial: 3D Visualization

Scroll the **Coronal Slices** to display the hemispheric white matter model in the context of the image data in the 3D Viewer.



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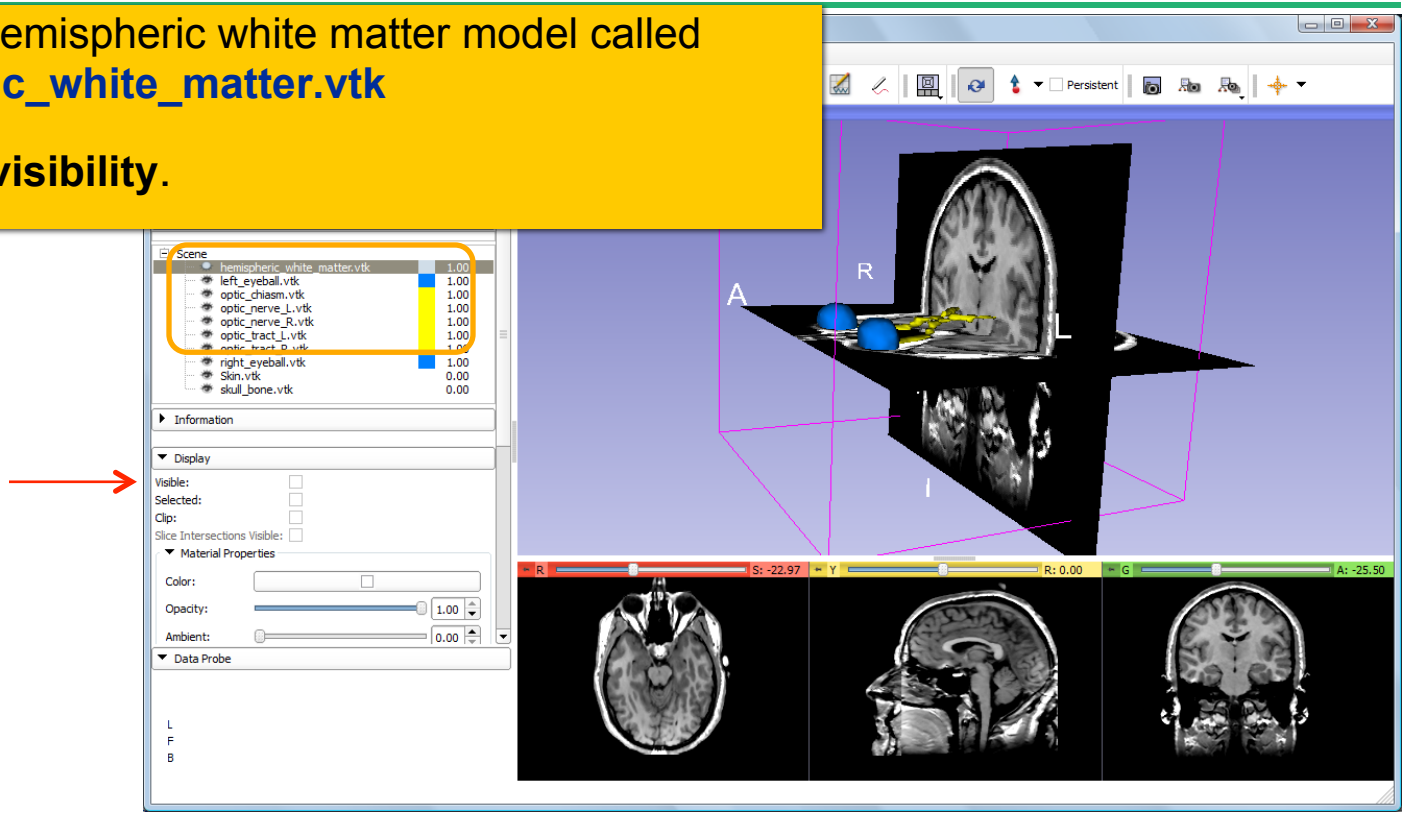
Slicer4 Minute Tutorial: 3D Visualization

Select the hemispheric white matter model called **hemispheric_white_matter.vtk**

Turn off its **visibility**.



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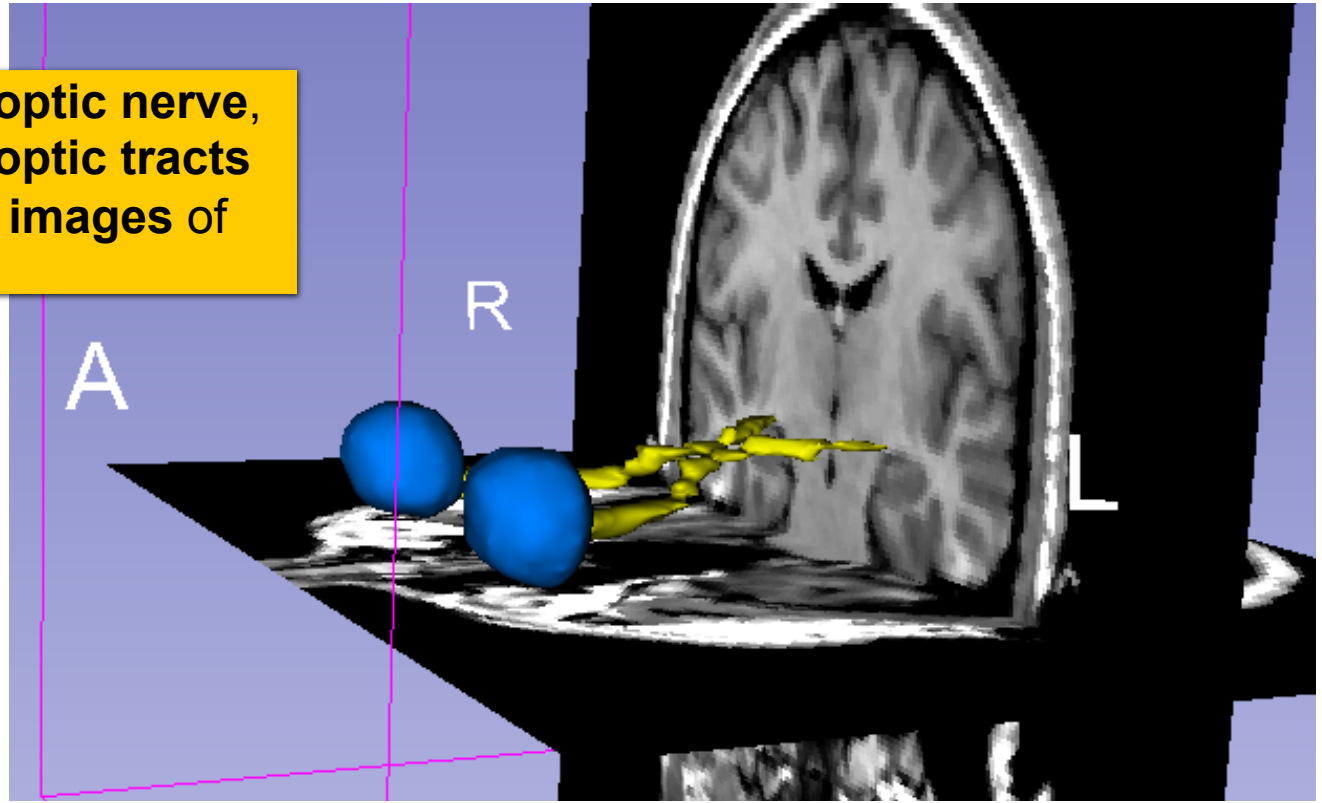
Slicer4 Minute Tutorial: 3D Visualization

Slicer displays the **optic nerve**, **optic chiasm** and **optic tracts** overlaid on the **MR images** of the brain.



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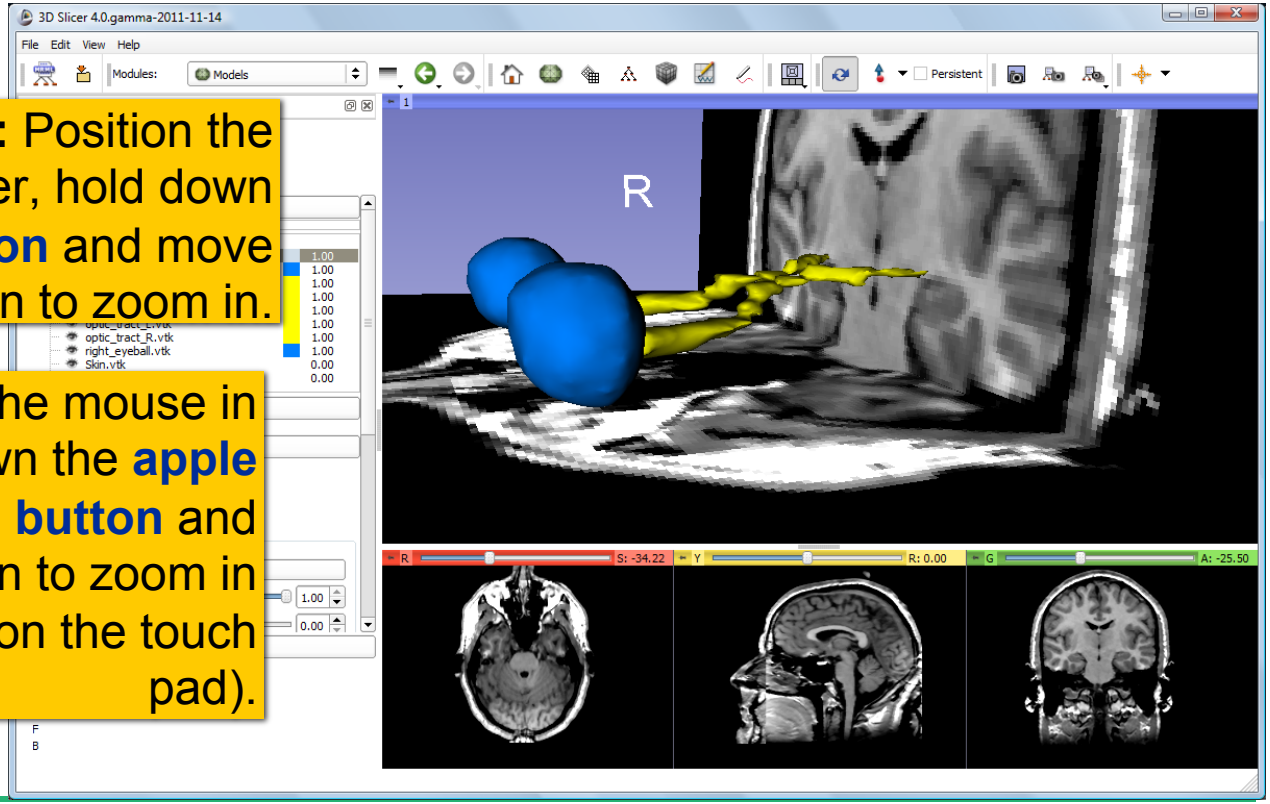
Slicer4 Minute Tutorial: 3D Visualization: Zoom the view

Windows/Linux users: Position the mouse in the 3D Viewer, hold down the **right mouse button** and move the mouse down to zoom in.

Mac users: Position the mouse in the 3D Viewer, hold down the **apple button and the mouse button** and move the mouse down to zoom in (or use two fingers on the touch pad).



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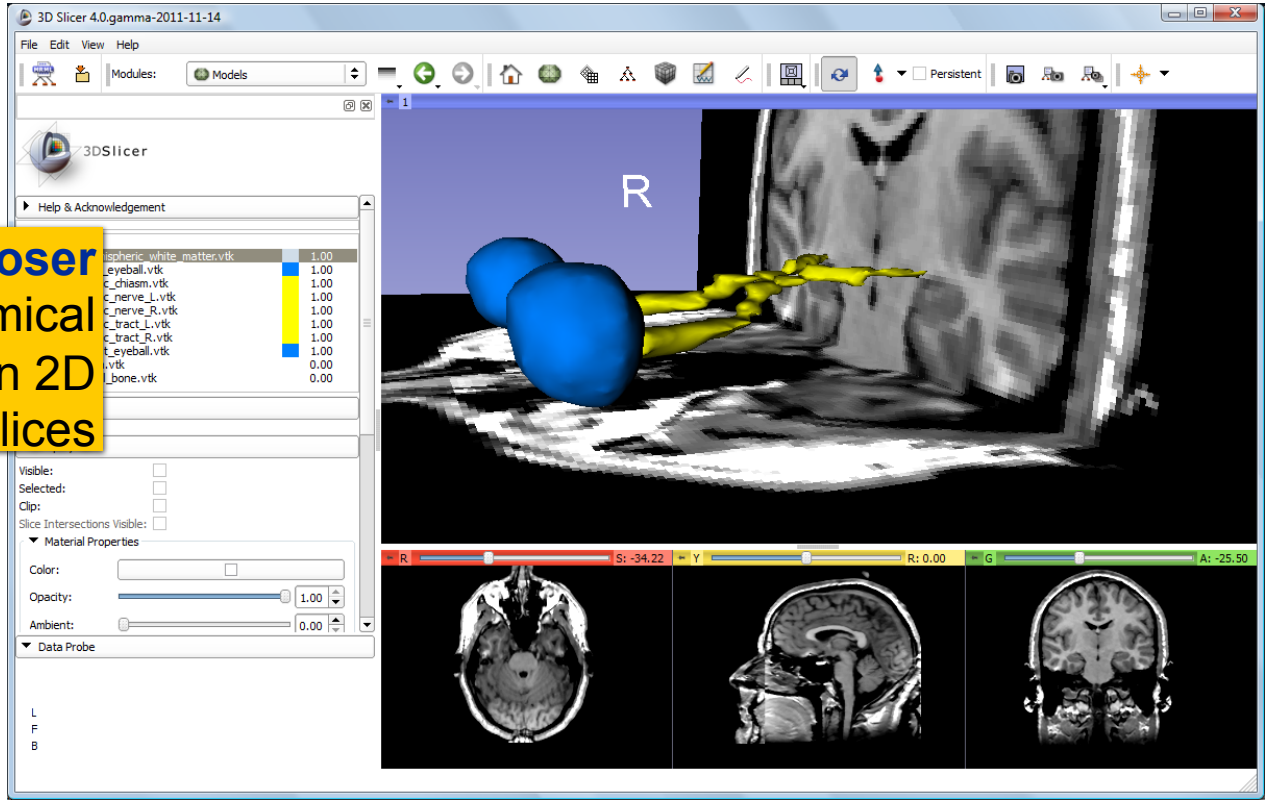
Slicer4 Minute Tutorial: 3D Visualization: Zoom the view

Slicer displays a **closer view** of 3D anatomical structures overlaid on 2D MR slices



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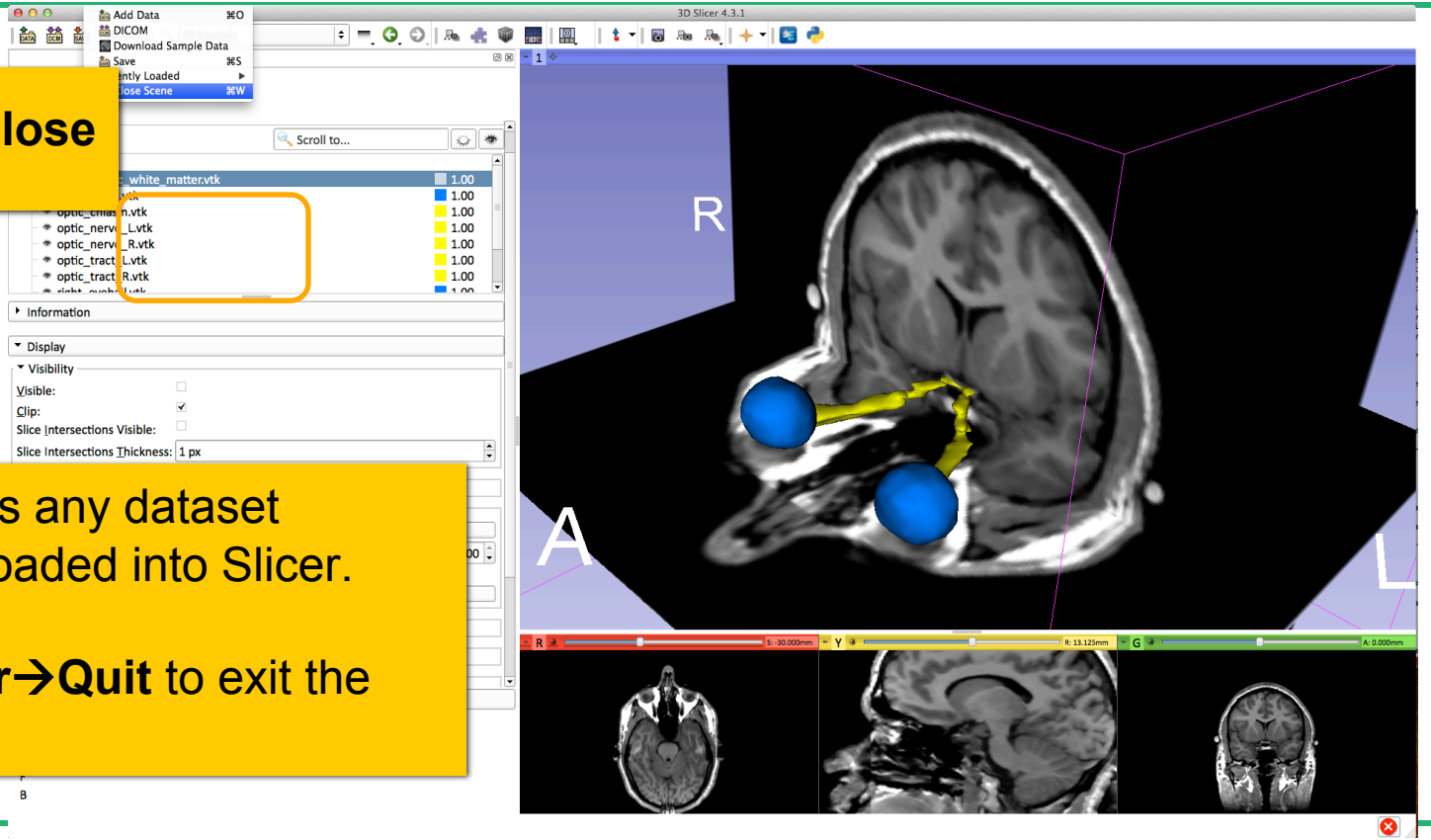
Close the existing scene and all its data

Select **File->Close Scene**



This removes any dataset previously loaded into Slicer.

Select **Slicer→Quit** to exit the software

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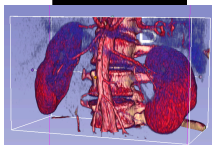
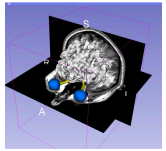
Overview

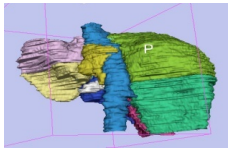
Part I: Introduction to the 3DSlicer software



Part II: 3D Data Loading and visualization of DICOM images

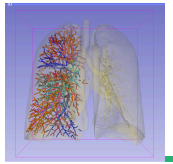
- Volume Rendering of thoraco-abdominal CT data
- Surface Rendering of MR head data





Part III: 3D interactive exploration of the anatomy

- Exploration of the Segments of the liver
- Exploration of the Segments of the lung



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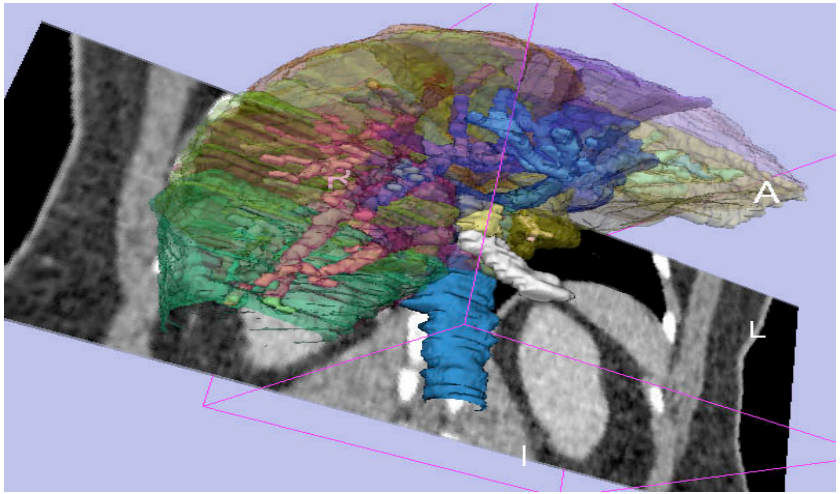

Part II:

Interactive 3D Visualization of the segments of the liver

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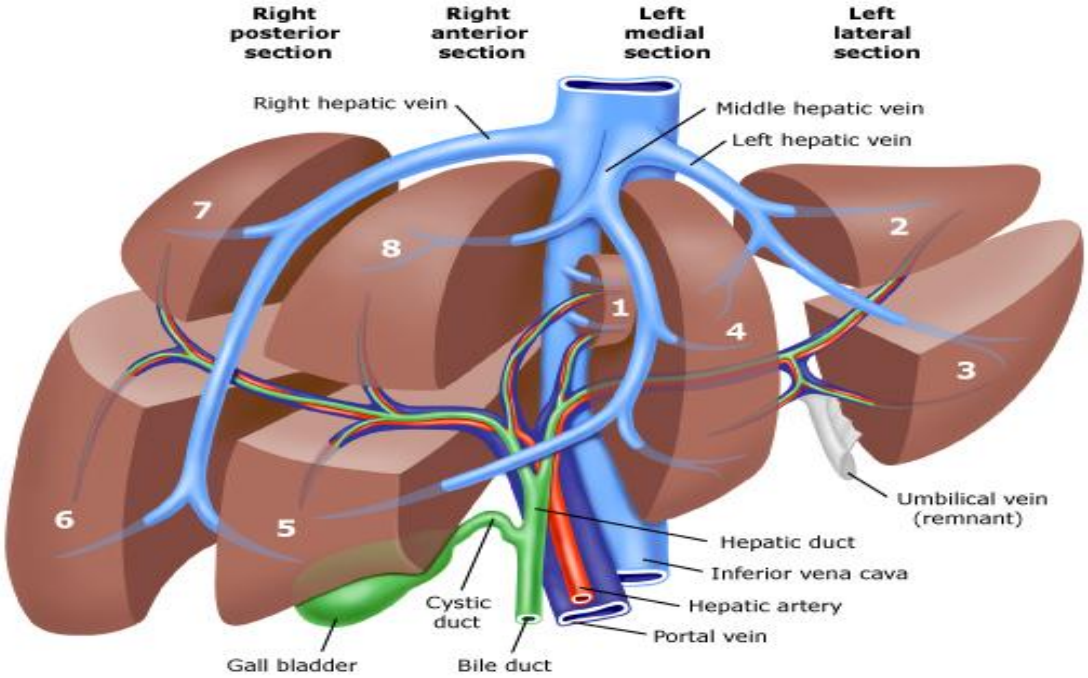
Anatomy of the liver



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Liver dataset

The liver dataset is a contrast-enhanced CT abdominal scan of a healthy 36 year-old male.

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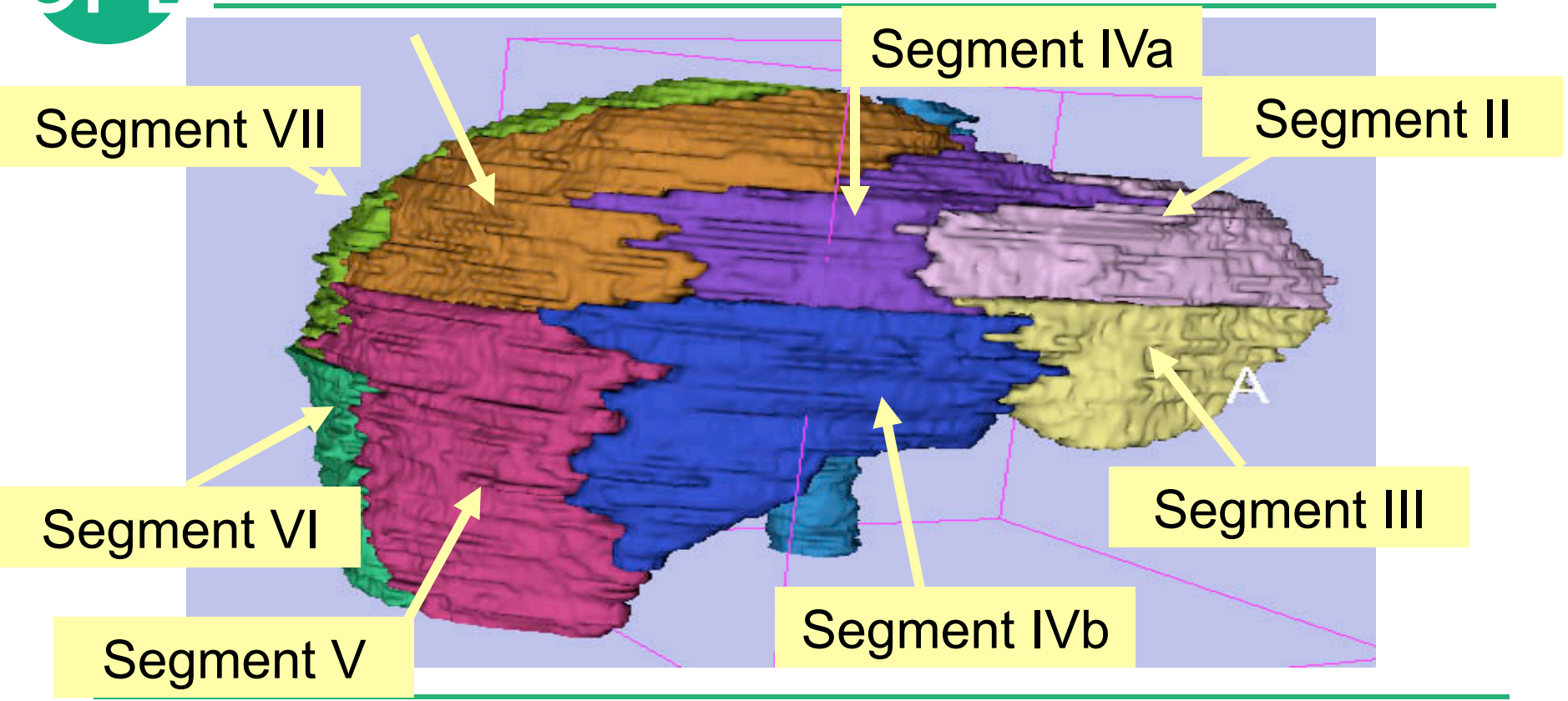
3D segments of the liver



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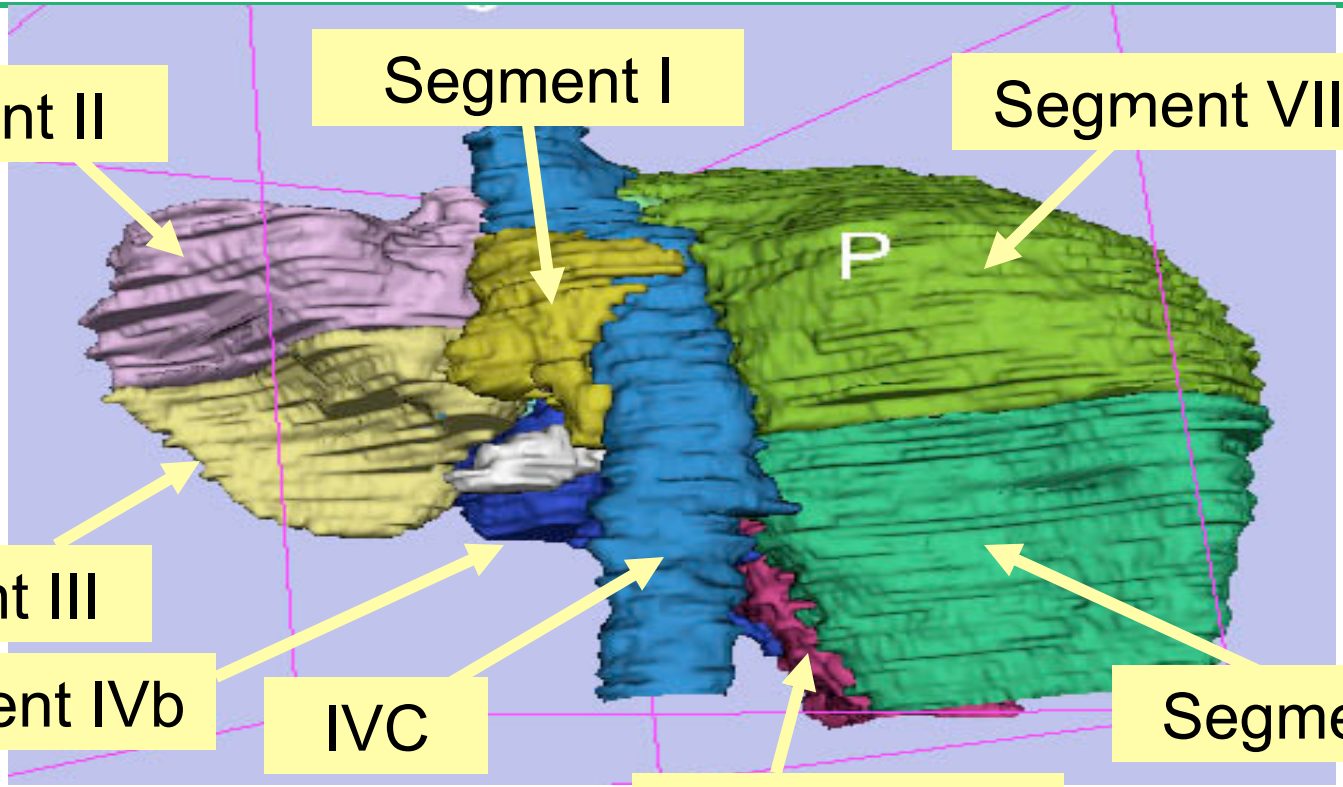
3D segments of the liver



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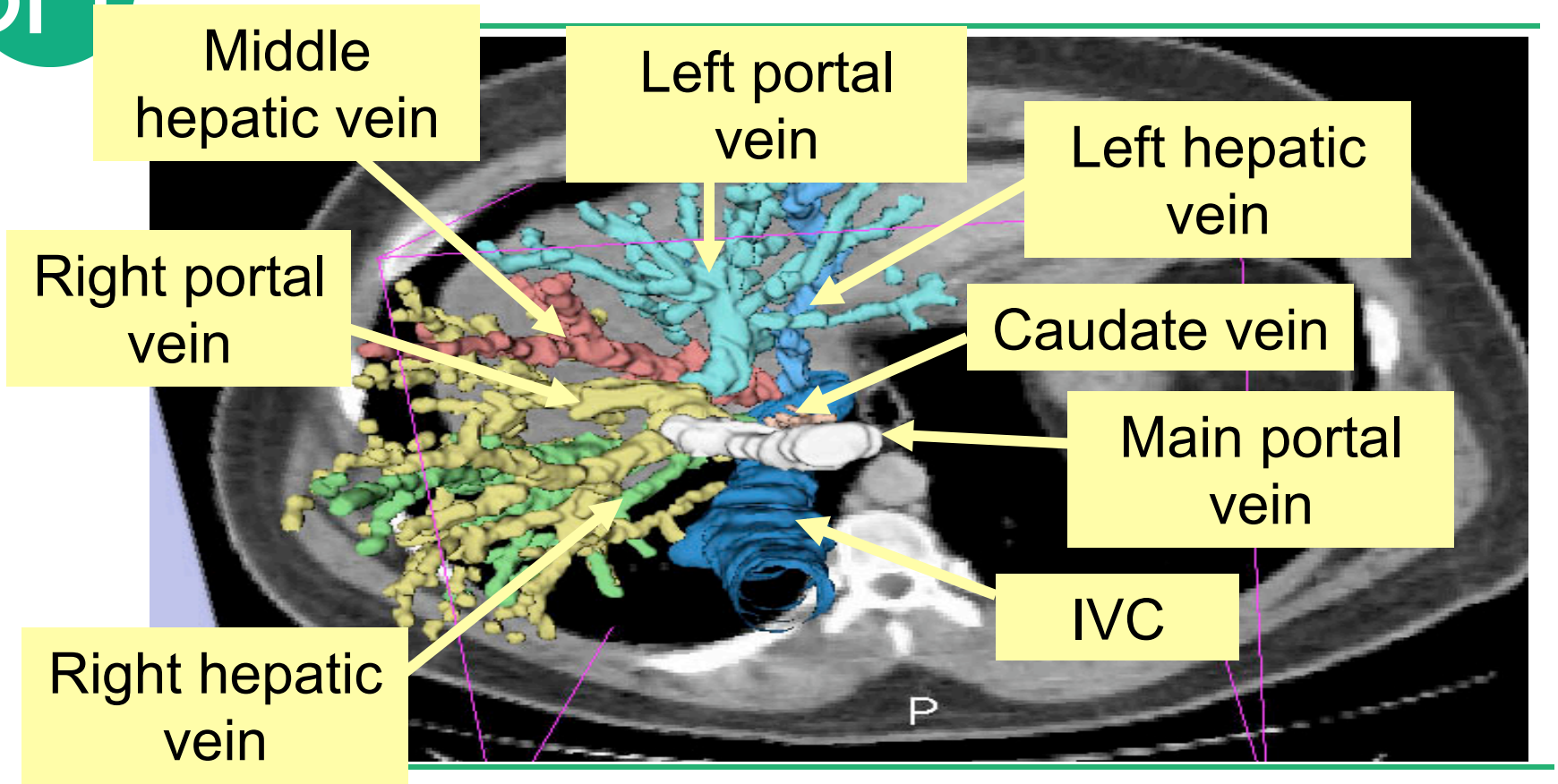
Liver vasculature



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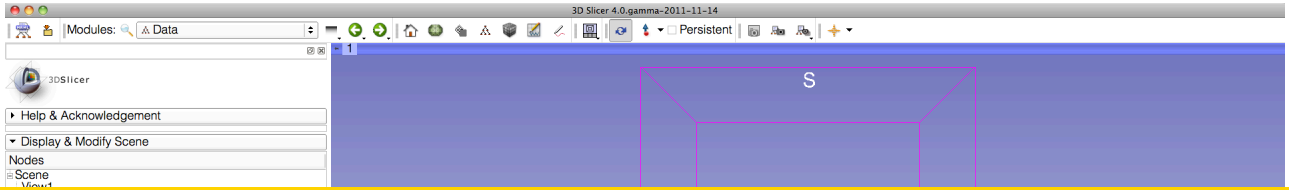
Loading the Liver Scene



Browse to the directory

C:\3DSlicerData_RSNA2013\3DVisualizationDICOM_Tuesday_Dec3

Select the directory **dataset3_Liver**

Drag and drop the file **LiverSegments_Scene.mrb** into Slicer

Click on OK to load the scene into Slicer

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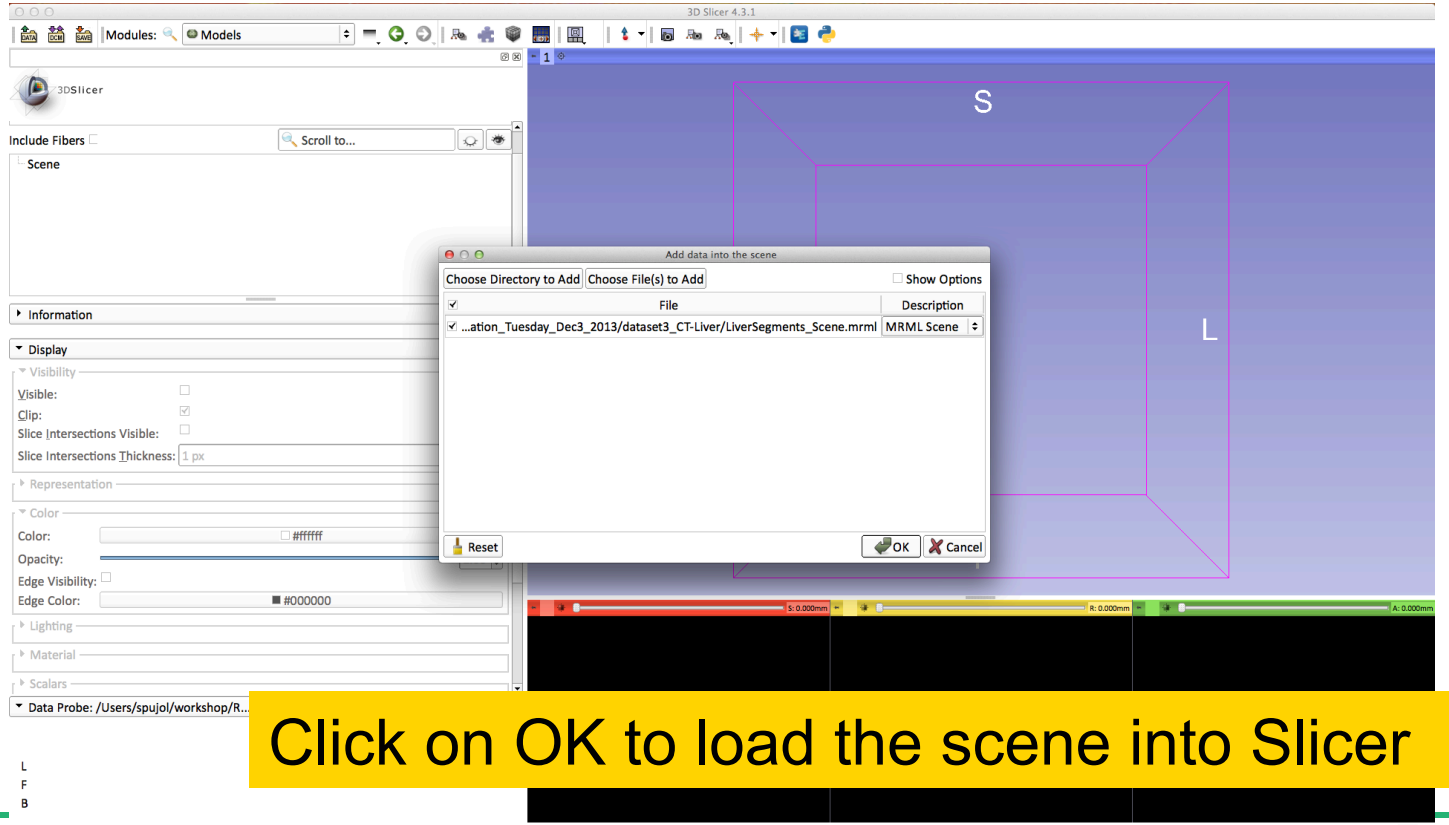
Loading the Liver Scene



Click on OK to load the scene into Slicer

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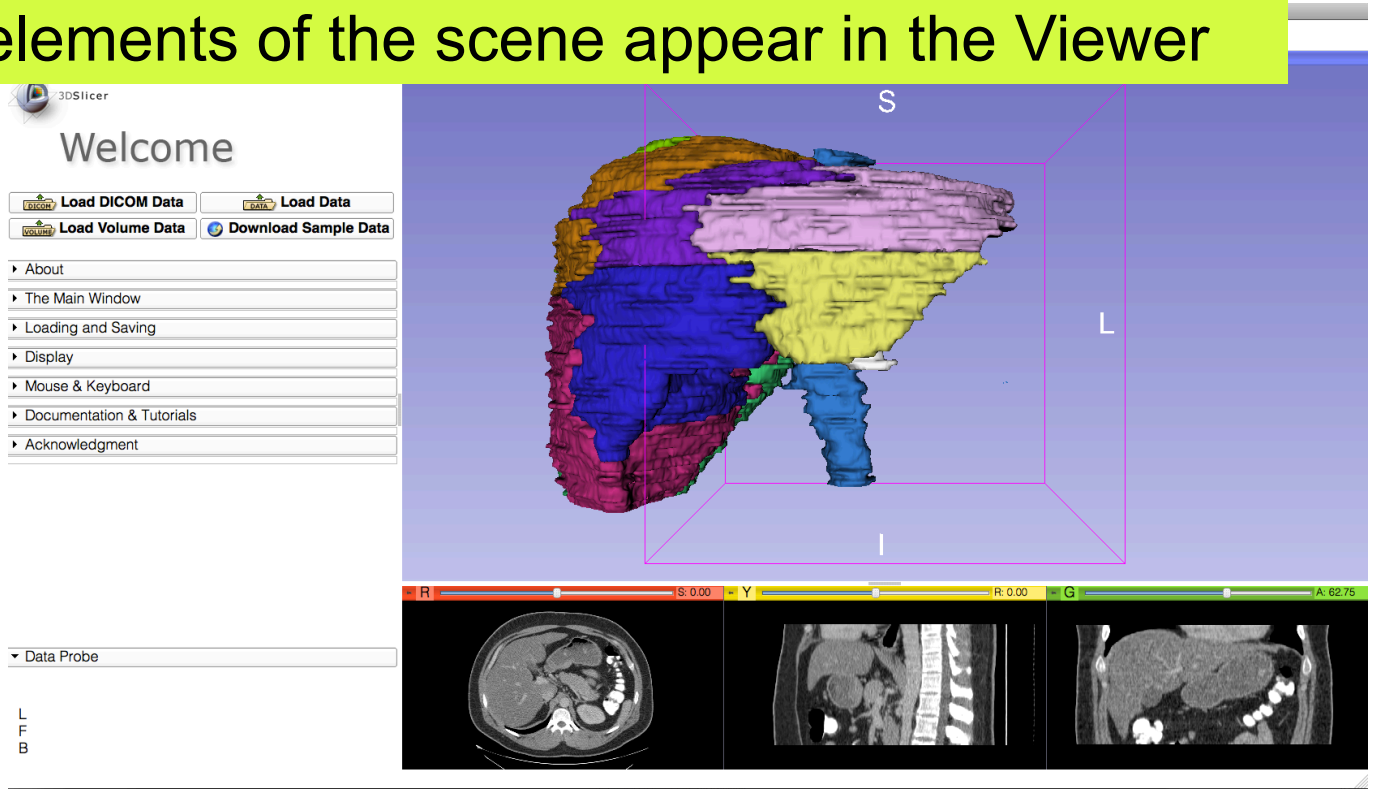
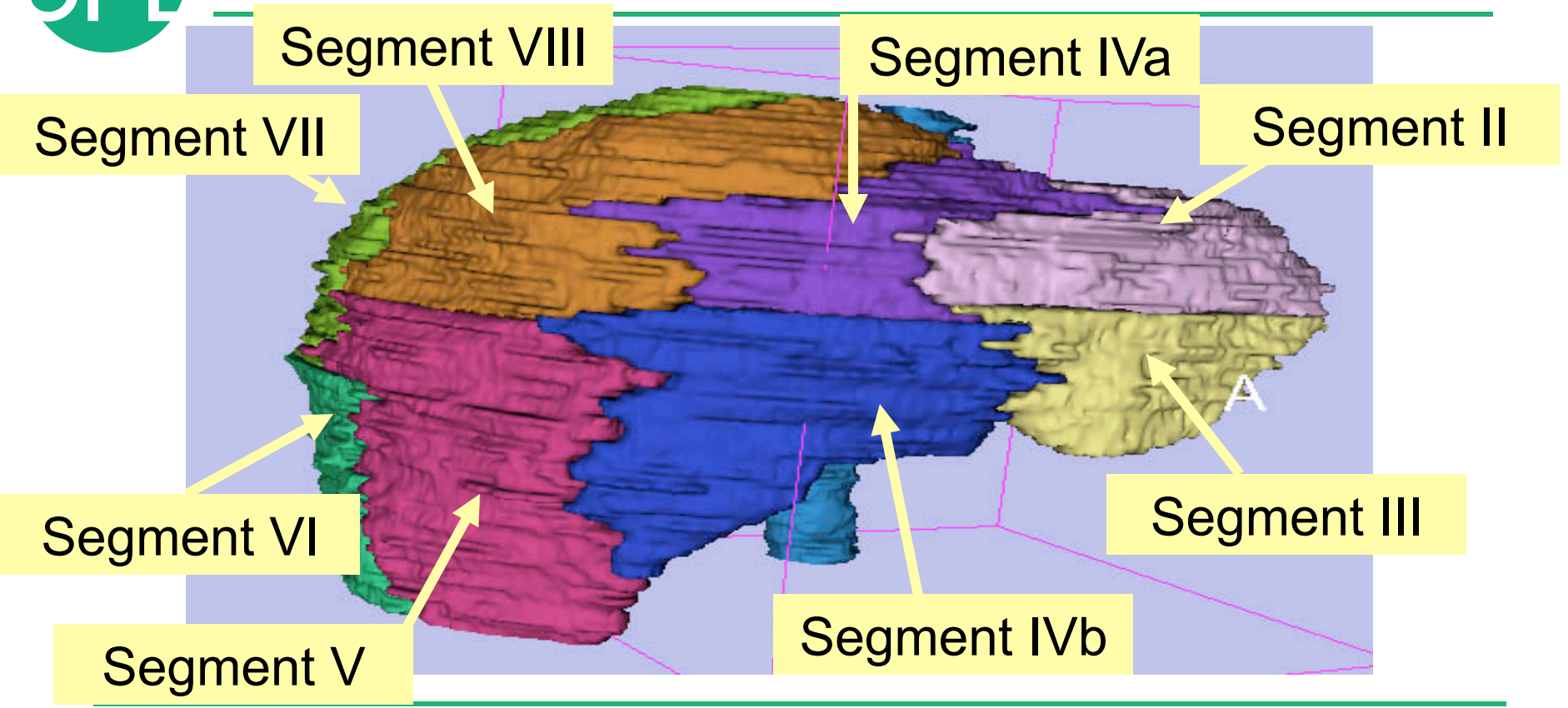
Liver Segments Scene

The elements of the scene appear in the Viewer



©2012-2013 Surgical Planning Laboratory, ARR

3D models of the liver



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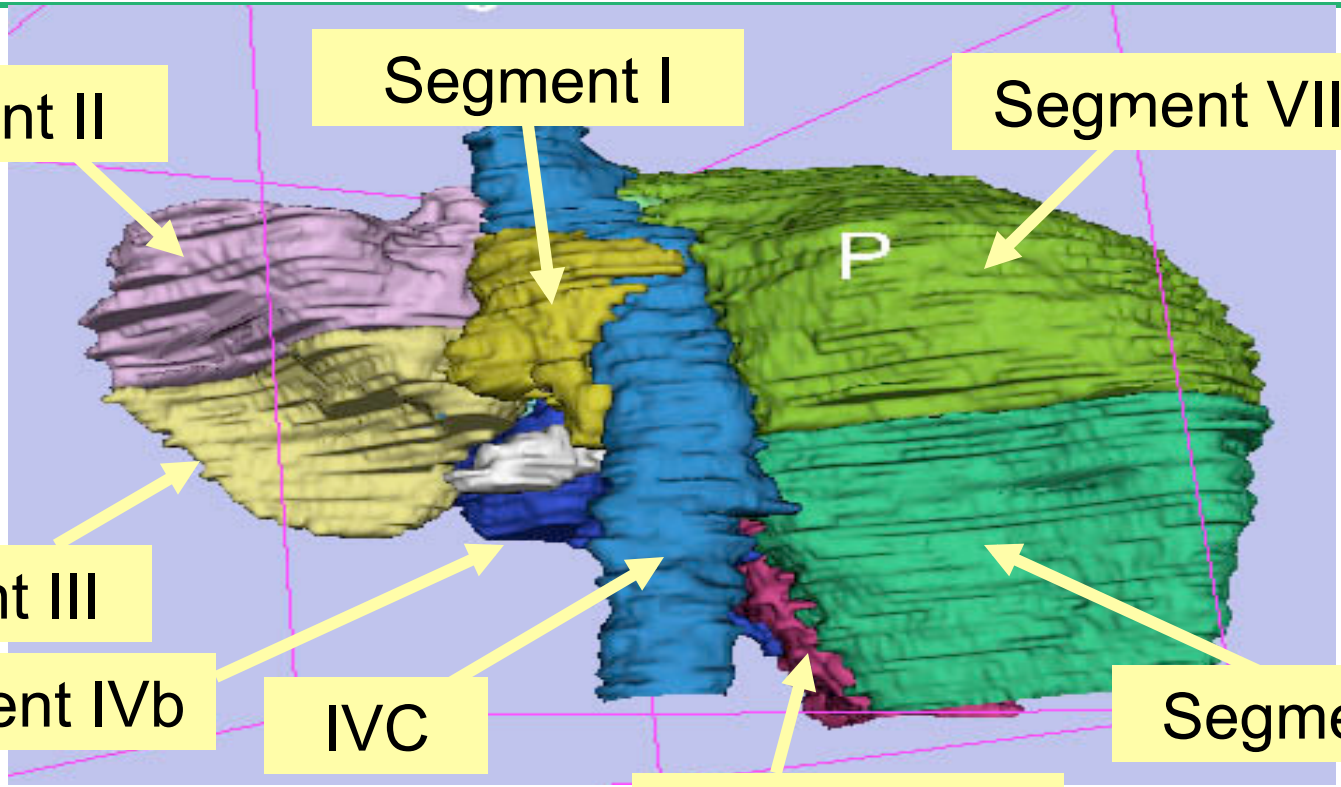
3D models of the liver



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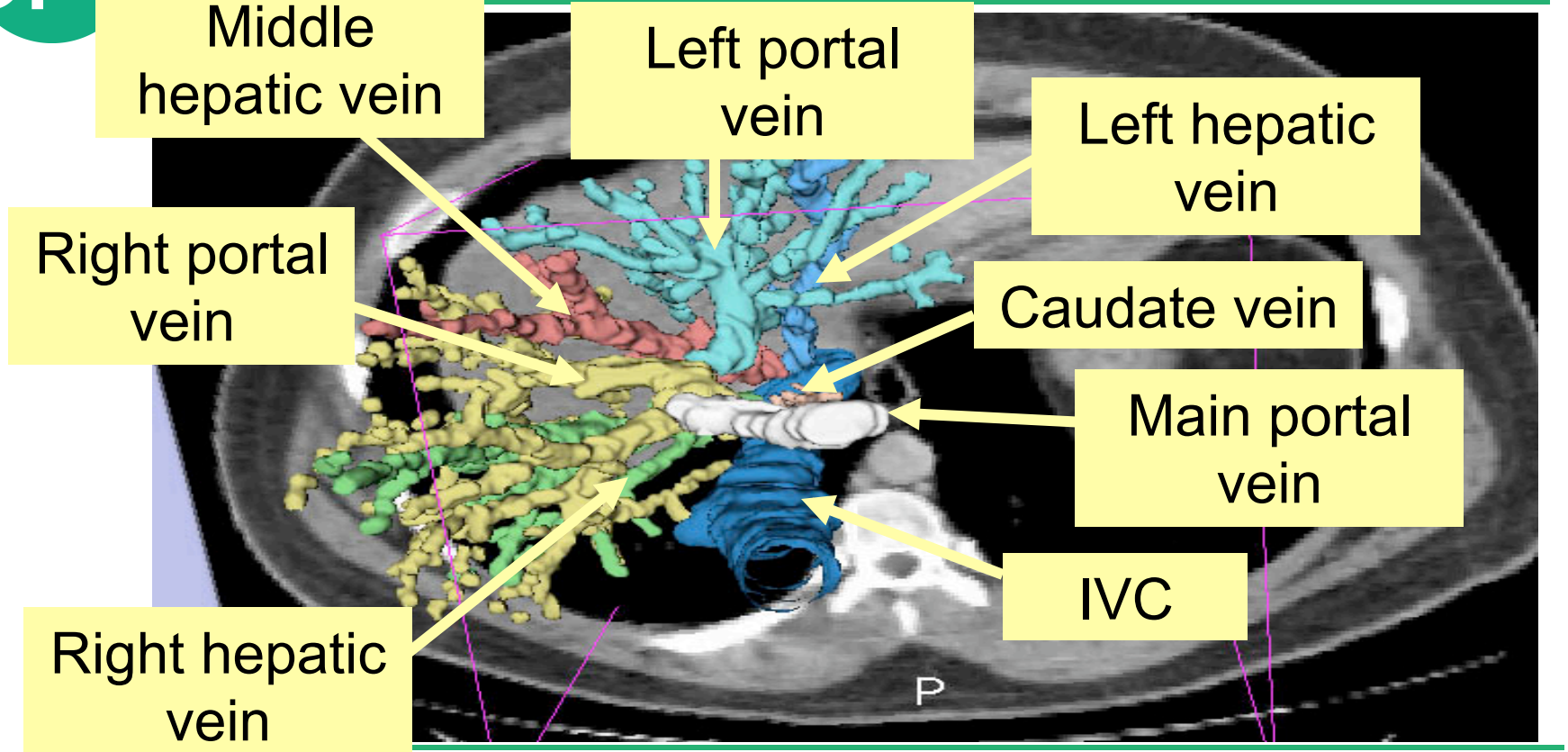
3D models of the liver



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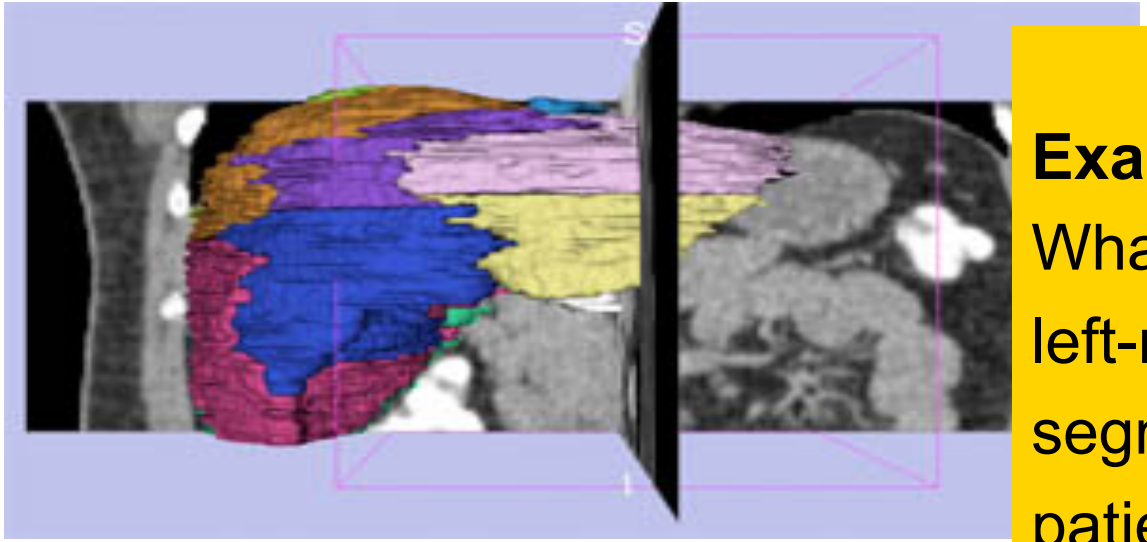
3D Exploration of Liver Segments



Example:

What organ abuts the left-most margin of segment II in this patient ?

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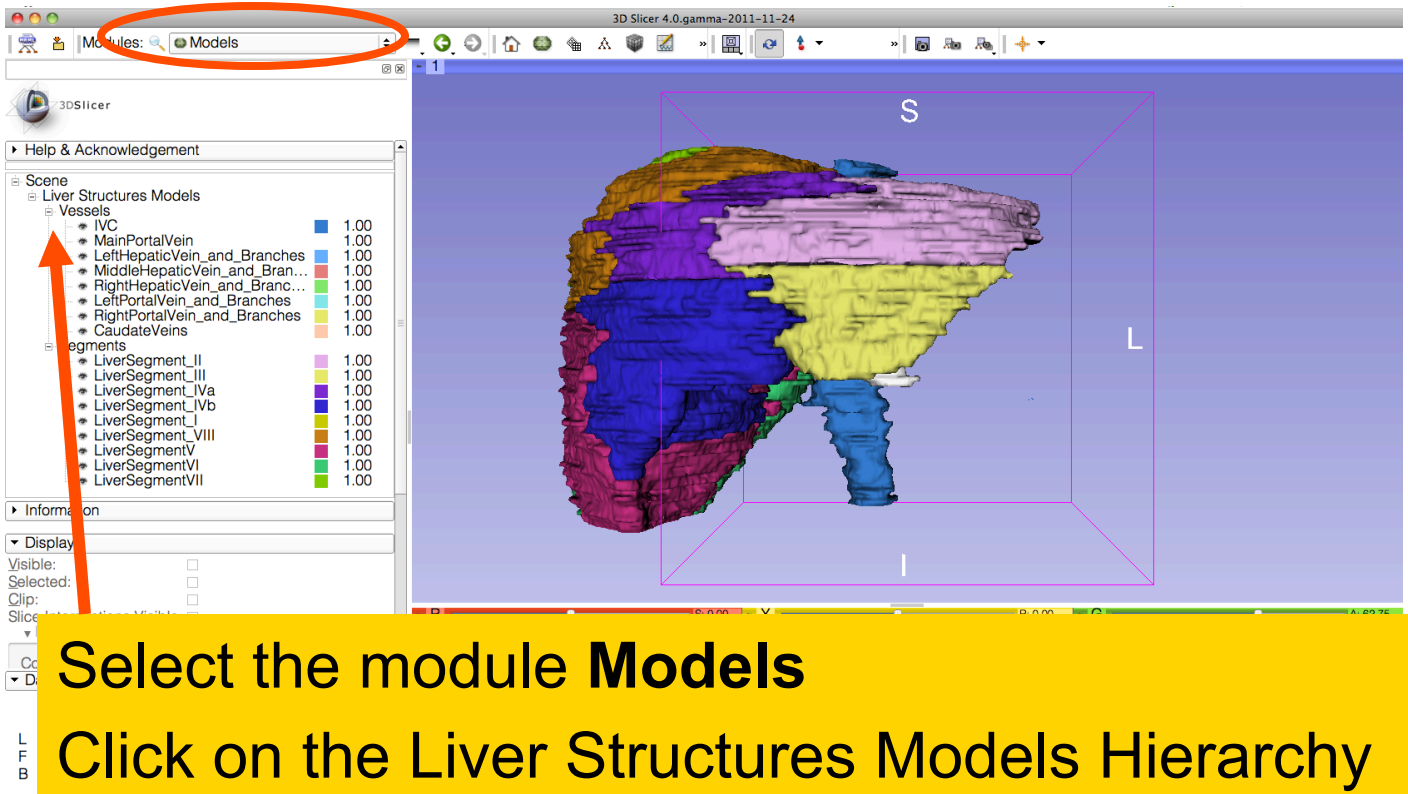
3D Exploration of Liver Segments



Select the module **Models**

Click on the Liver Structures Models Hierarchy

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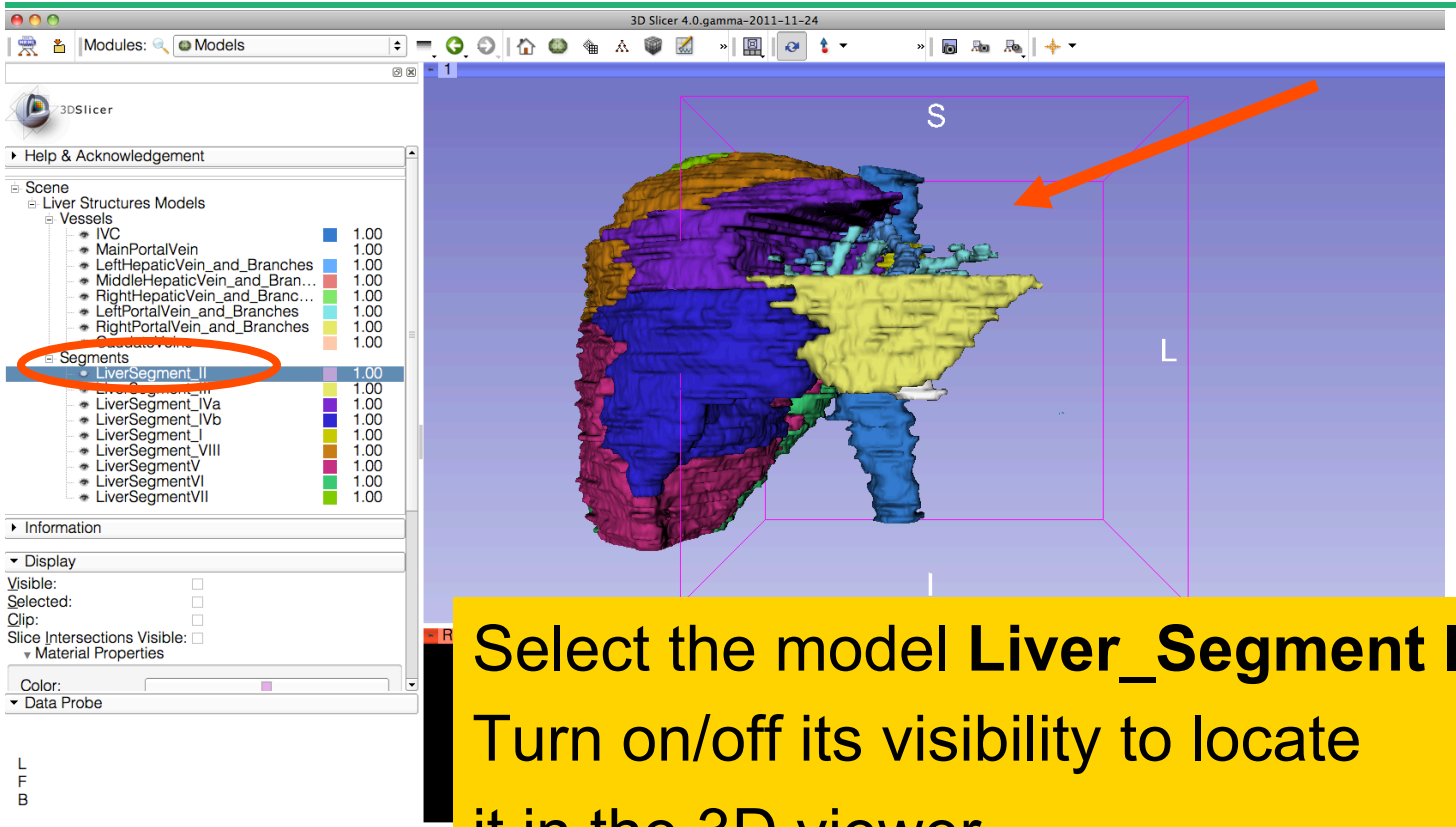
3D Exploration of Liver Segments



Select the model **Liver_Segment II**

Turn on/off its visibility to locate it in the 3D viewer.

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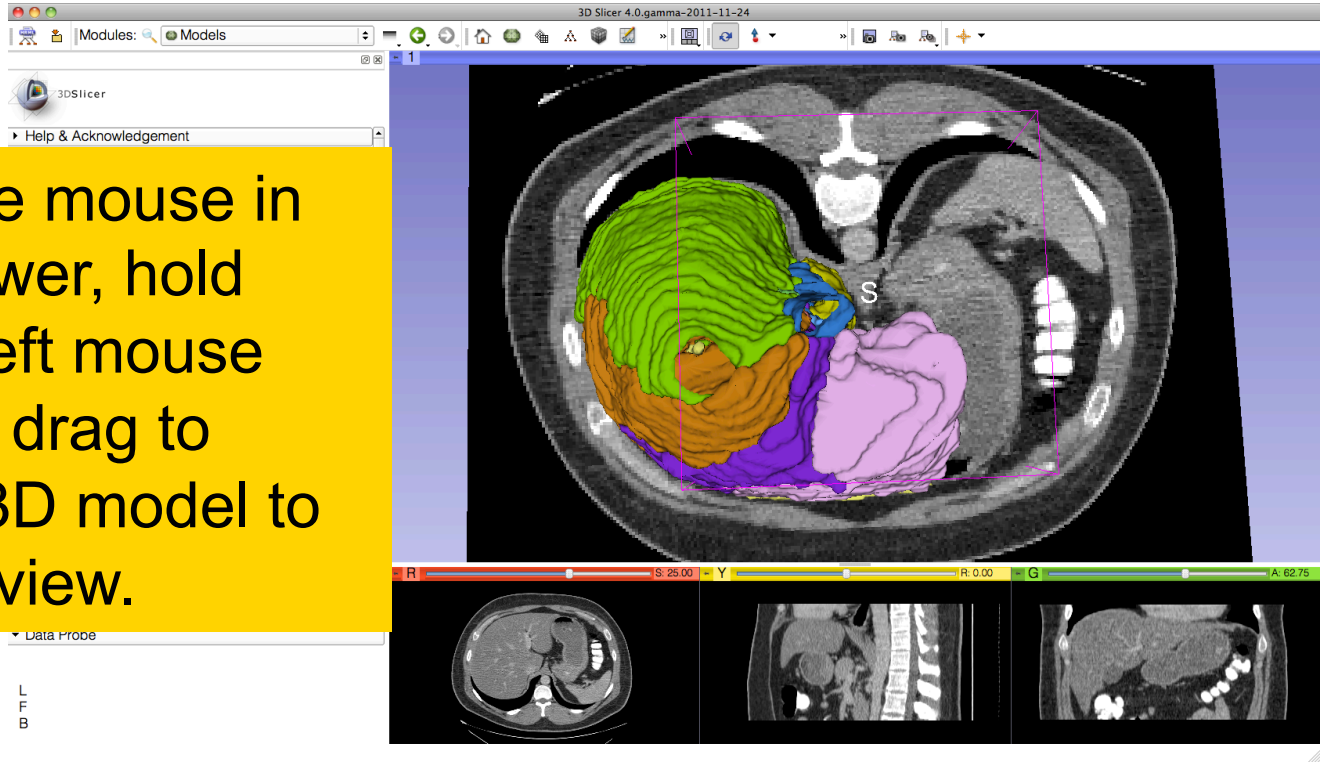
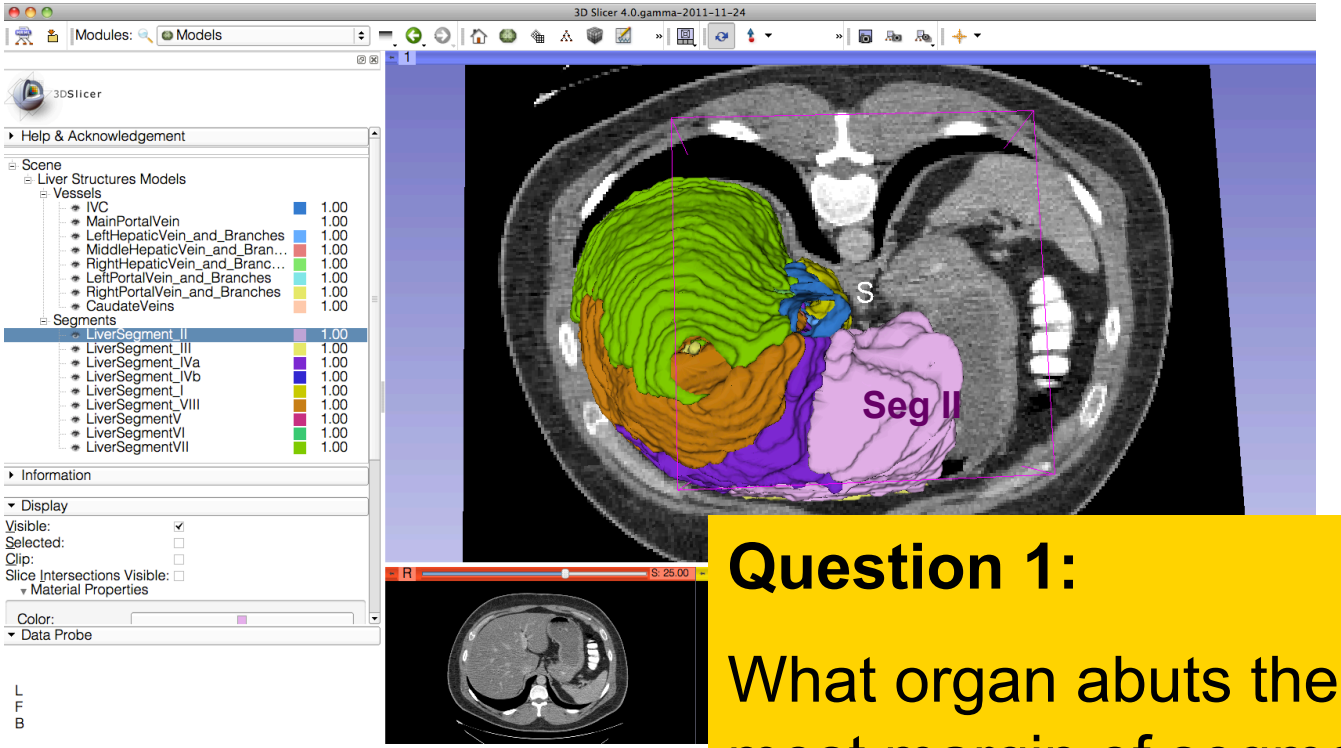
3D Exploration of Liver Segments

Position the mouse in the 3D Viewer, hold down the left mouse button and drag to orient the 3D model to a superior view.



3D Exploration of Liver Segments



Question 1:

What organ abuts the left-most margin of segment II in Patient 1?

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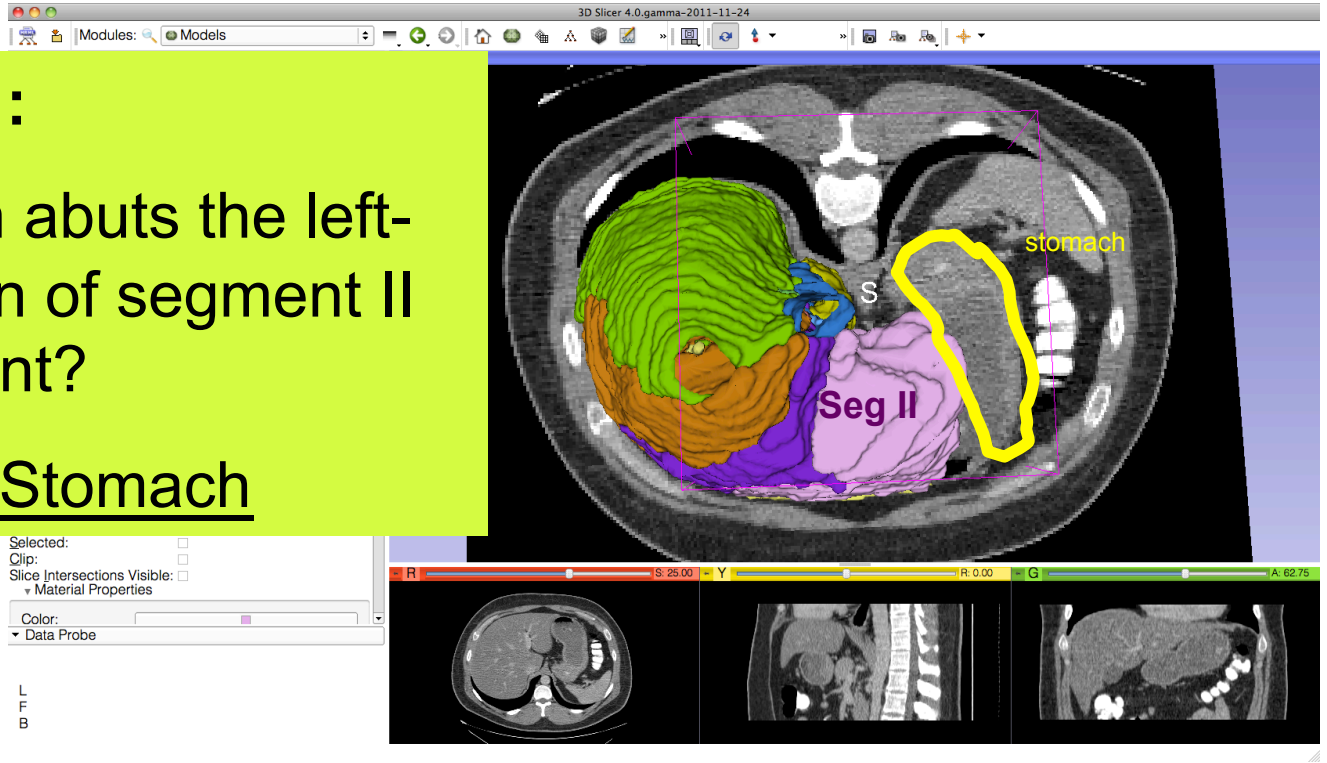
3D Exploration of Liver Segments

Question 1:

What organ abuts the left-most margin of segment II in this patient?

Answer 1: Stomach



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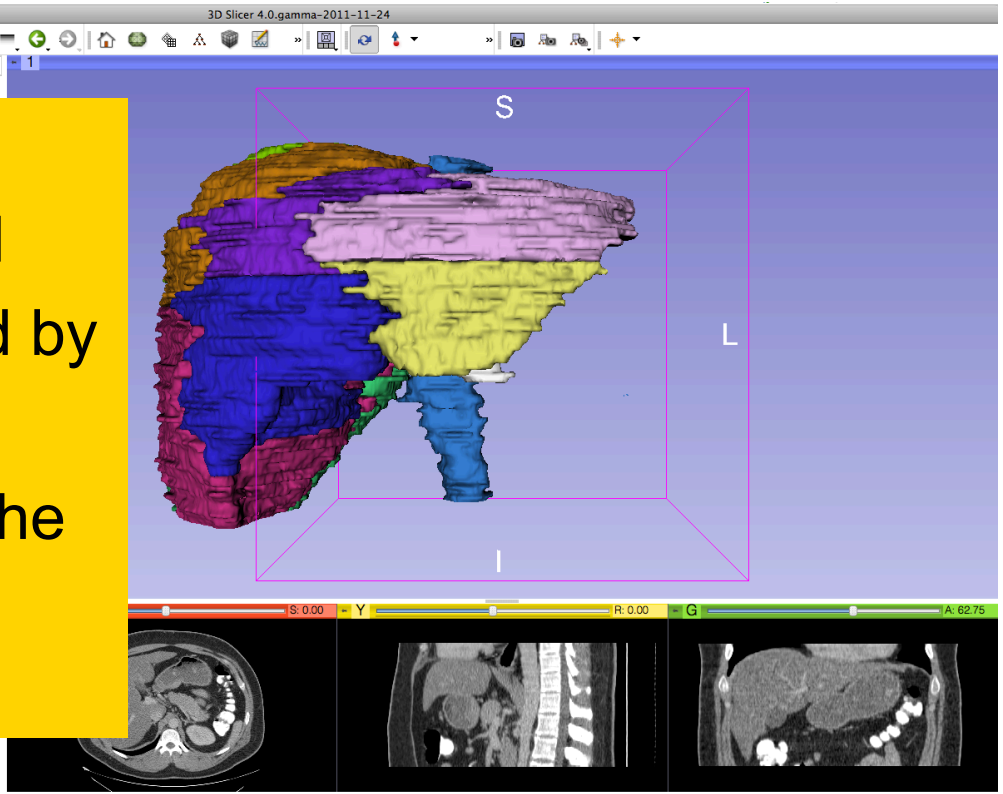
3D Exploration of Liver Segments

Question 2:

Which segment would most likely be affected by an aggressive tumor invading locally from the right adrenal gland ?



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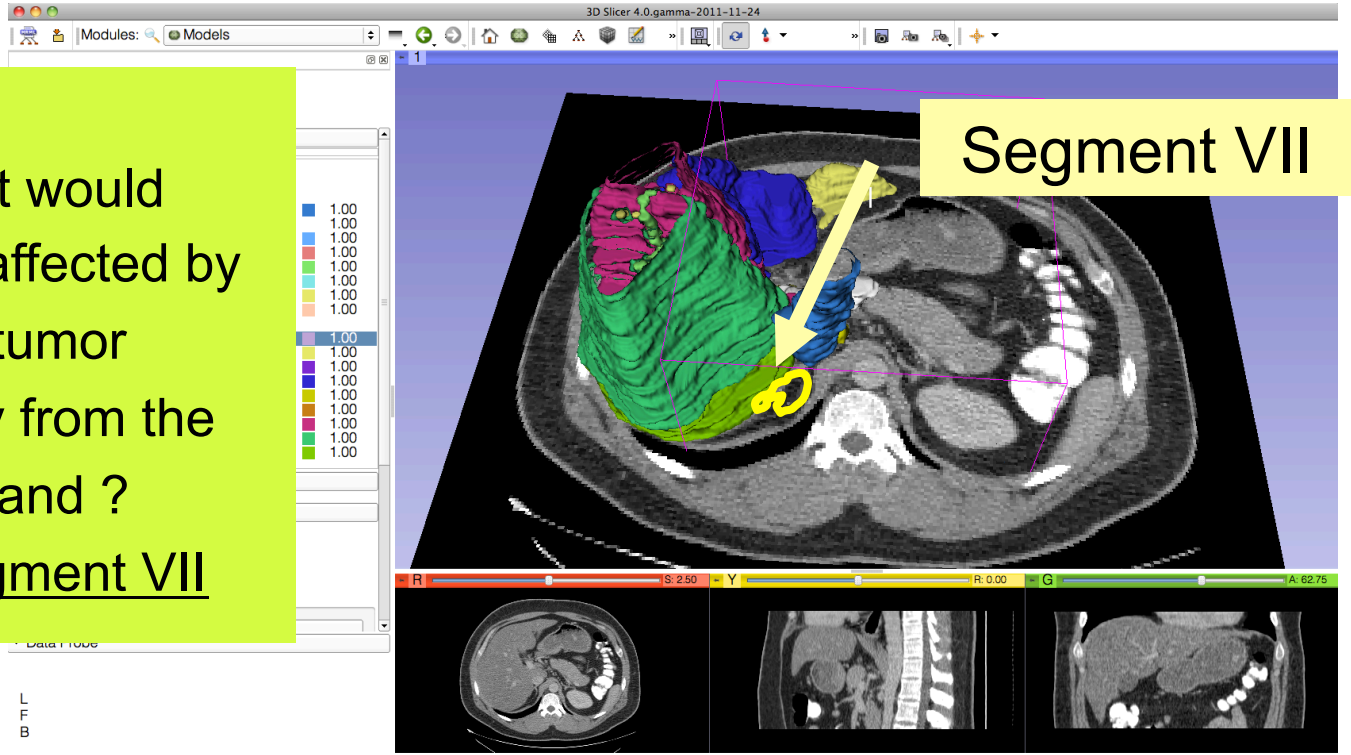
3D Exploration of Liver Segments

Question 2:

Which segment would most likely be affected by an aggressive tumor invading locally from the right adrenal gland ?

Answer 2: Segment VII



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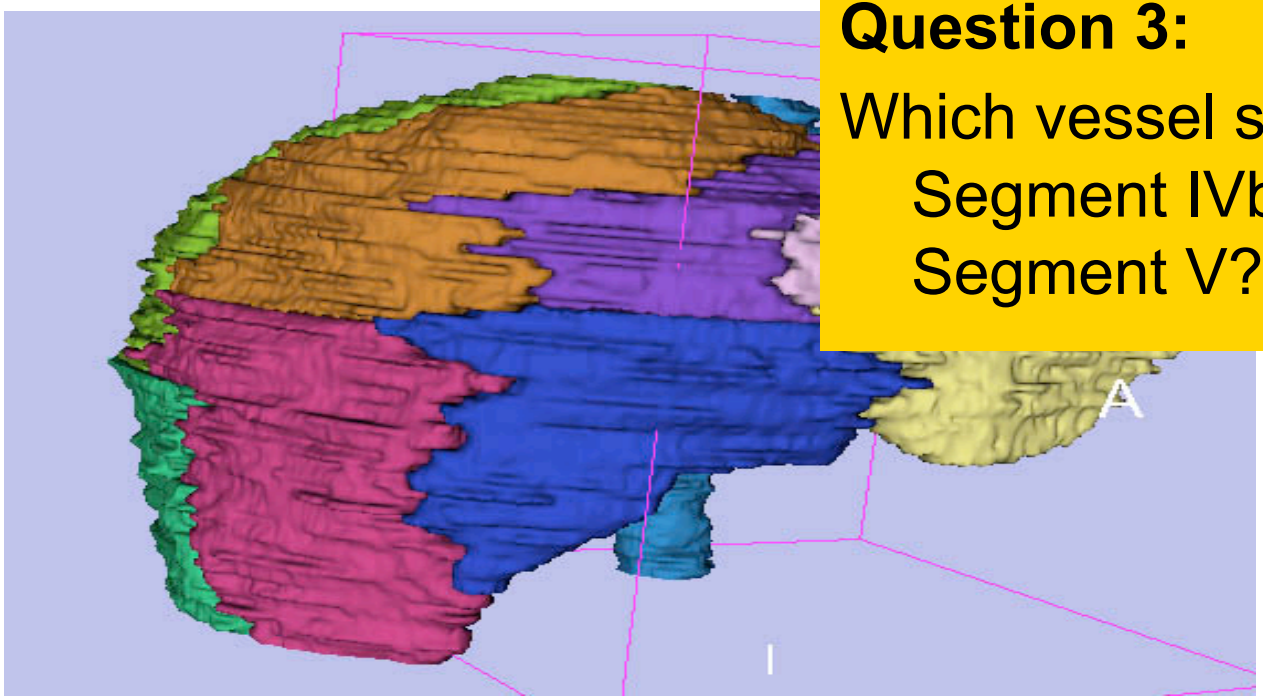
3D Exploration of Liver Segments



Question 3:

Which vessel separates Segment IVb and Segment V?

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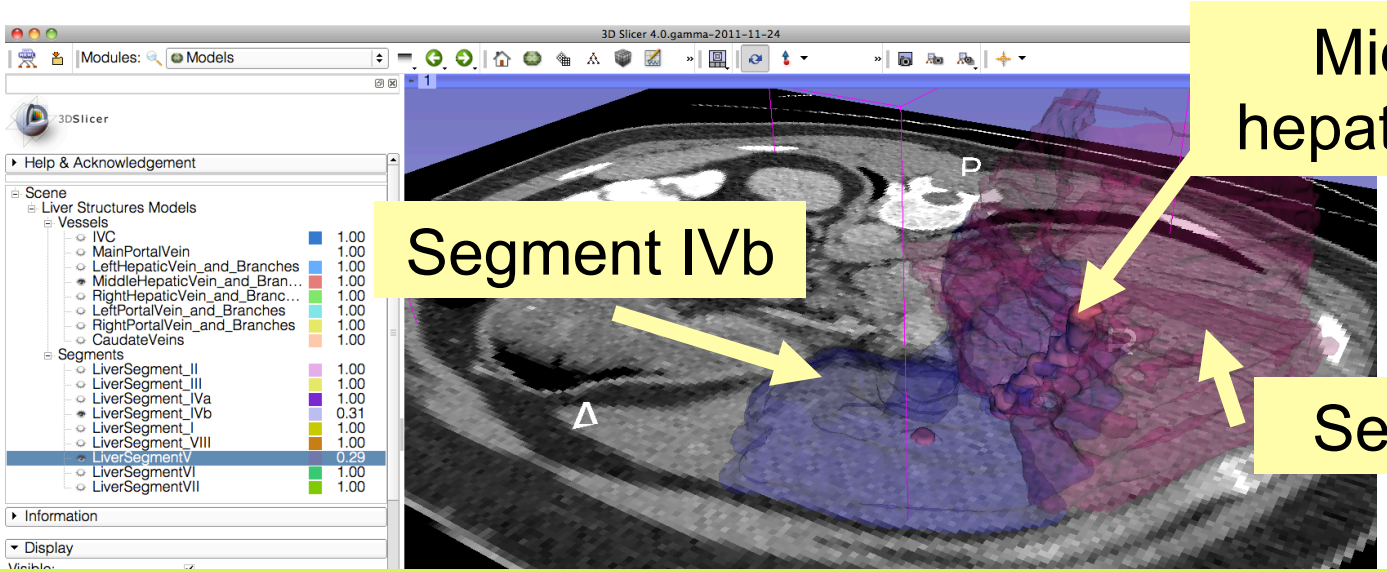
Middle Hepatic Vein



Question 3:

Which vessel separates Segment IVb and Segment V?

Answer 3: The middle hepatic vein

Closing the Liver Scene

Select **Slicer → Exit** to close the Liver Scene and exit Slicer

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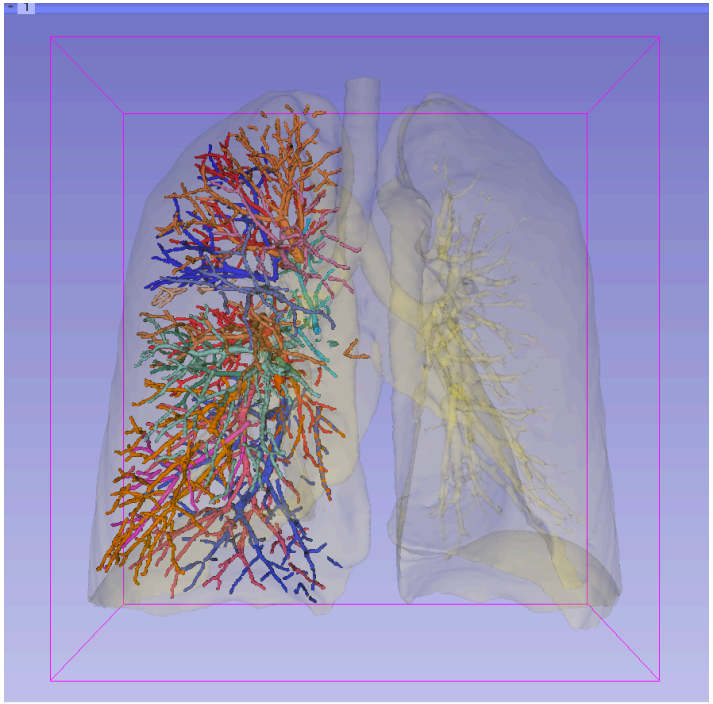

Interactive 3D Visualization of the segments of the lungs

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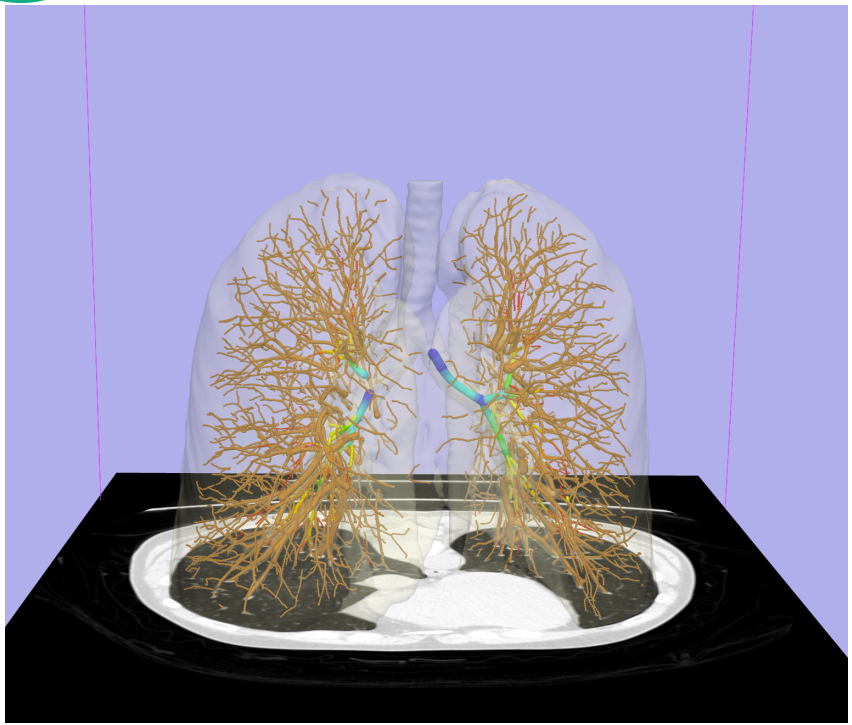
Segments of the lung



Segmentation and 3D surface reconstruction of the lung and pulmonary vessels

Acknowledgment:
Segmentation of the lung surface and vasculature: Raul San Jose Estepar, Ph.D., George Washko, M.D., Ed Silverman, M.D. and James Ross, MSc. Brigham and Women's Hospital (K25 HL104085) and COPDGene (01 HL089897 and U01 HL089856)

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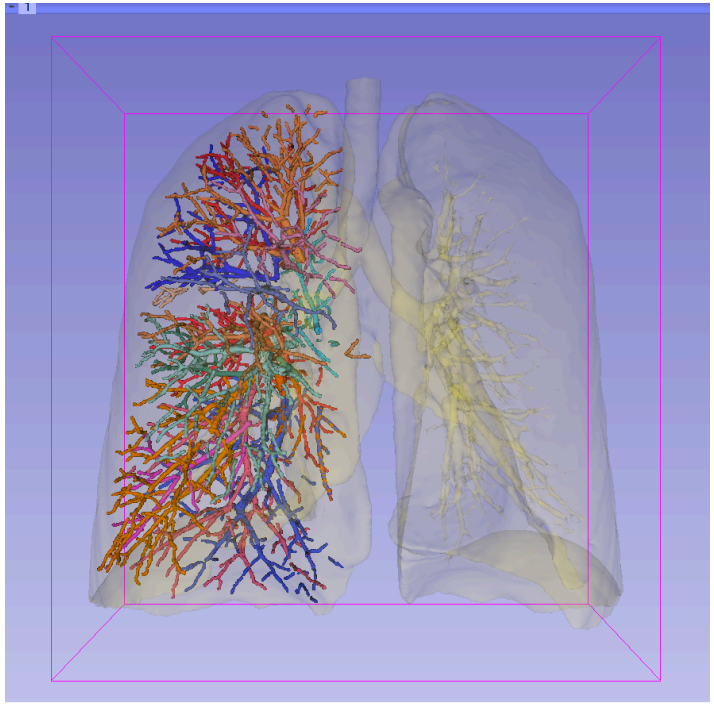
Segments of the lung



3D parcellation of arteries and veins from original model of pulmonary vessels
(Kitt Shaffer, M.D., Ph.D. - Sonia Pujol, Ph.D.)

- Right Upper Lobe (RUL)
  - RUL Pulmonary Vein
  - RUL Anterior Segment
  - RUL Apical Segment
  - RUL Posterior Segment
- Right Middle Lobe (RML)
  - RML Pulmonary Vein 1 & 2
  - RML Lateral Segment
  - RML Medial Segment
- Right Lower Lobe (RLL)
  - RLL Pulmonary Vein 1,2,3
  - RLL Anterior Basal Segment
  - RLL Medial Basal Segment
  - RLL Lateral Basal Segment
  - RLL Posterior Basal Segment

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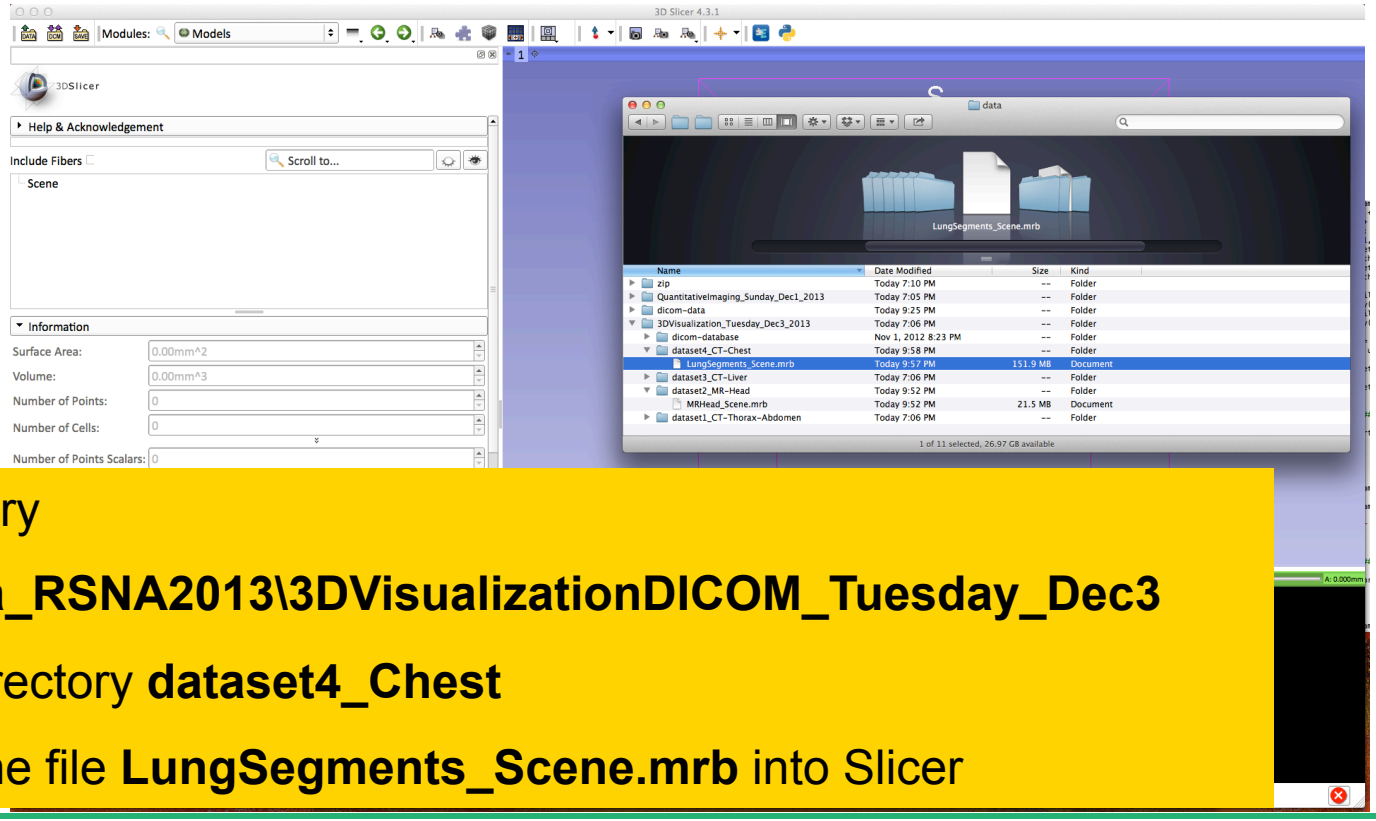
Loading the Chest Data Scene



Open the directory

C:\3DSlicerData_RSNA2013\3DVisualizationDICOM_Tuesday_Dec3

Select the subdirectory **dataset4_Chest**

Drag and drop the file **LungSegments_Scene.mrb** into Slicer

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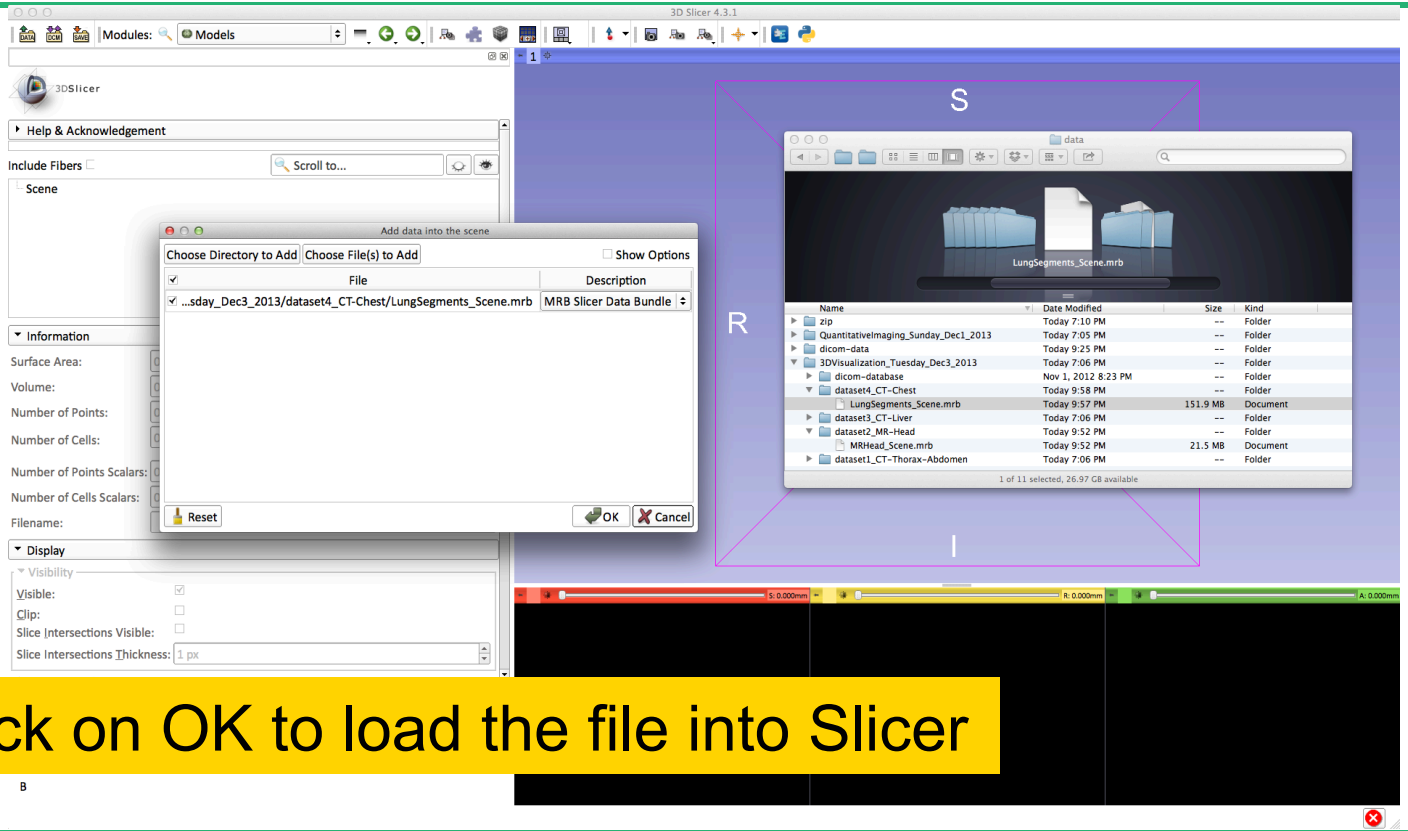
Loading the Lung Scene



Click on OK to load the file into Slicer

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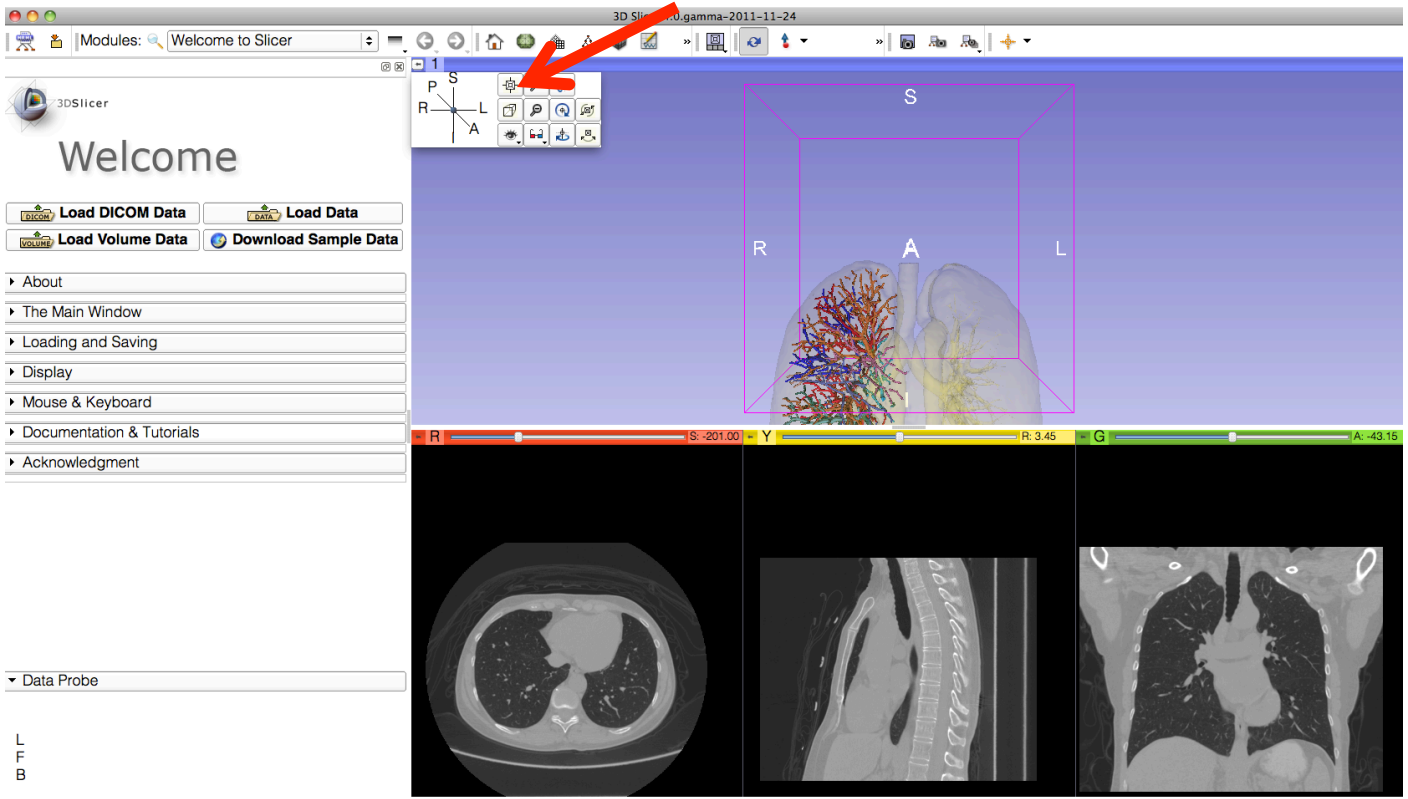
Loading the Lung Scene



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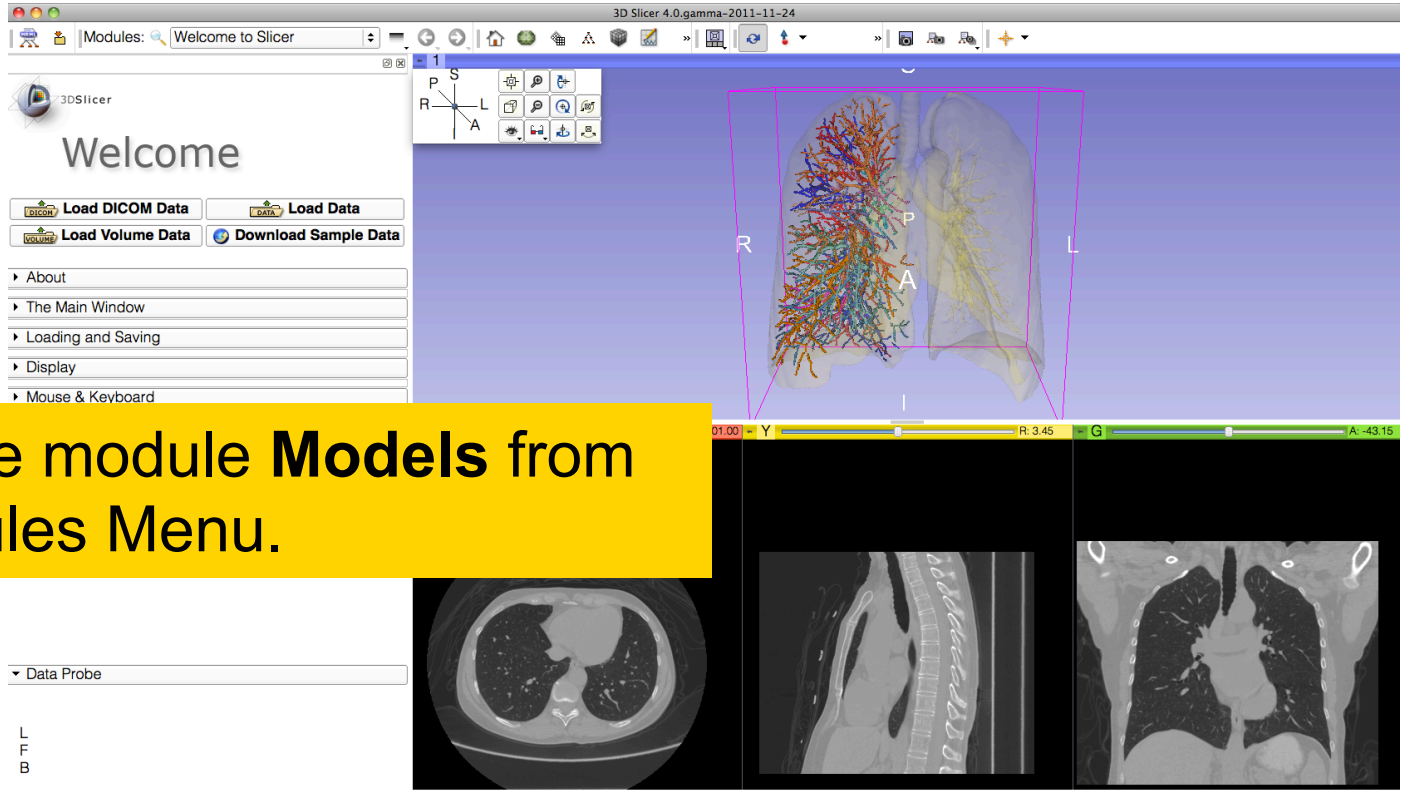
Loading the Lung Scene



Select the module **Models** from the modules Menu.

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Lung Segments

Slicer displays the list of 15 surface models of pulmonary structures.

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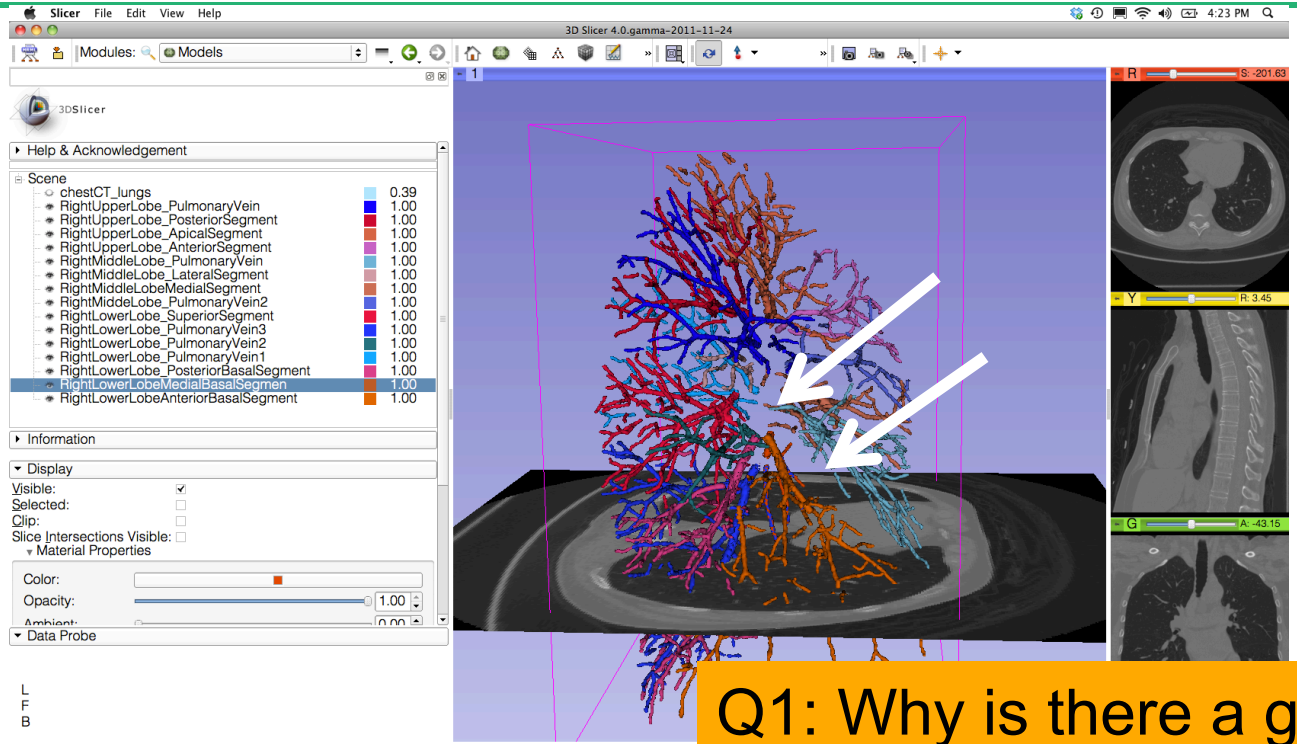
Lung Segments – Question 1



Q1: Why is there a gap in the vessels at the arrows?

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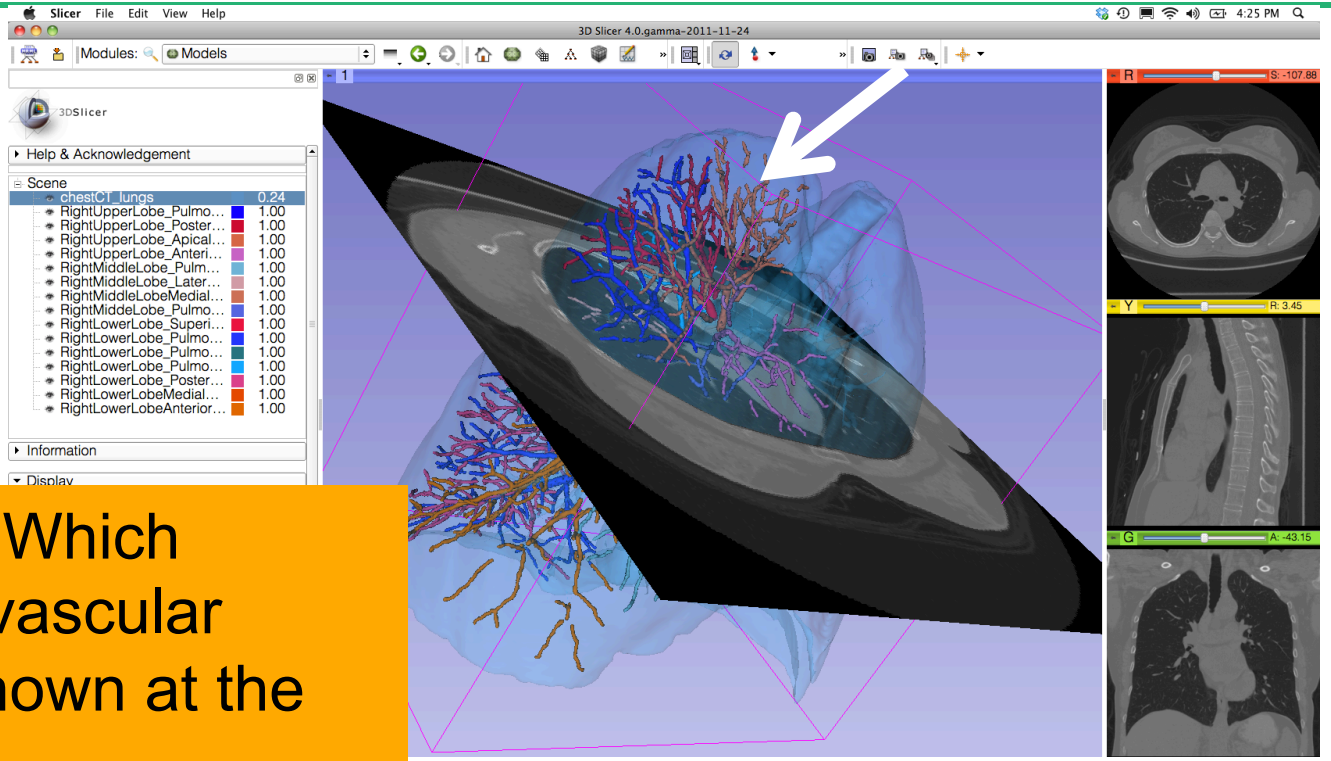
Lung Segments – Question 2



Question 2:Which segment's vascular supply is shown at the arrow?

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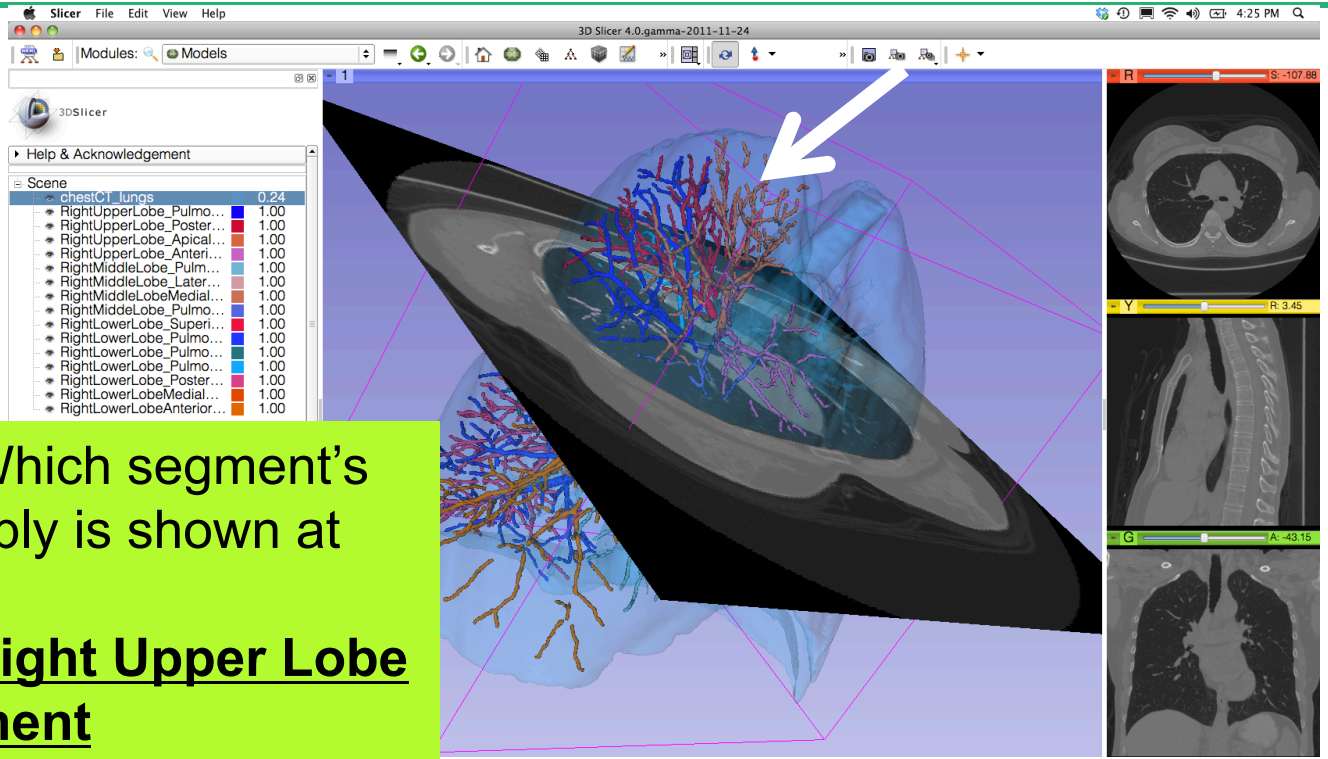
Lung Segments – Question 2



Question 2:Which segment's vascular supply is shown at the arrow?

Answer 2: Right Upper Lobe Apical Segment

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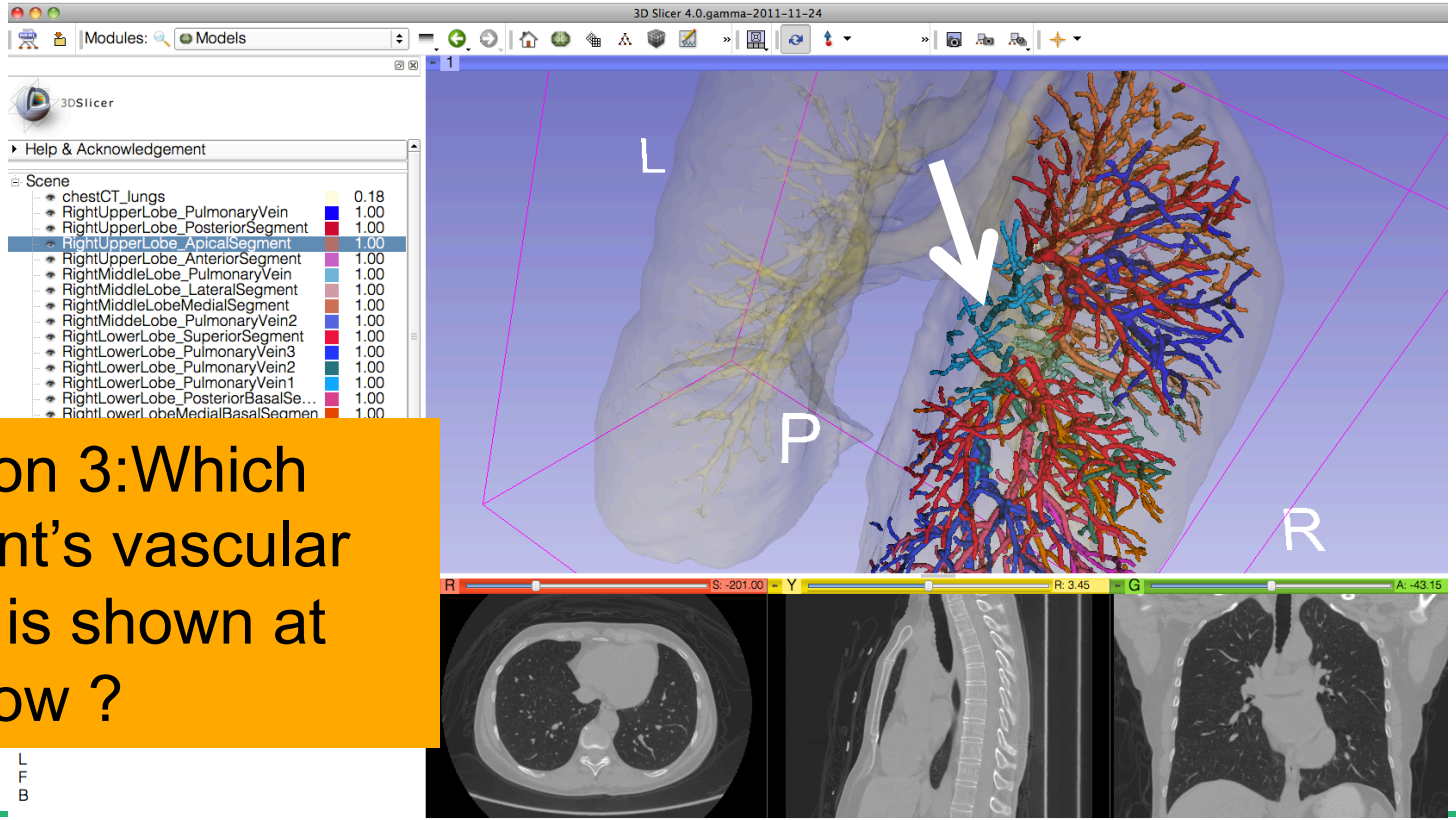
Lung Segments – Question 3



Question 3:Which segment's vascular supply is shown at the arrow ?

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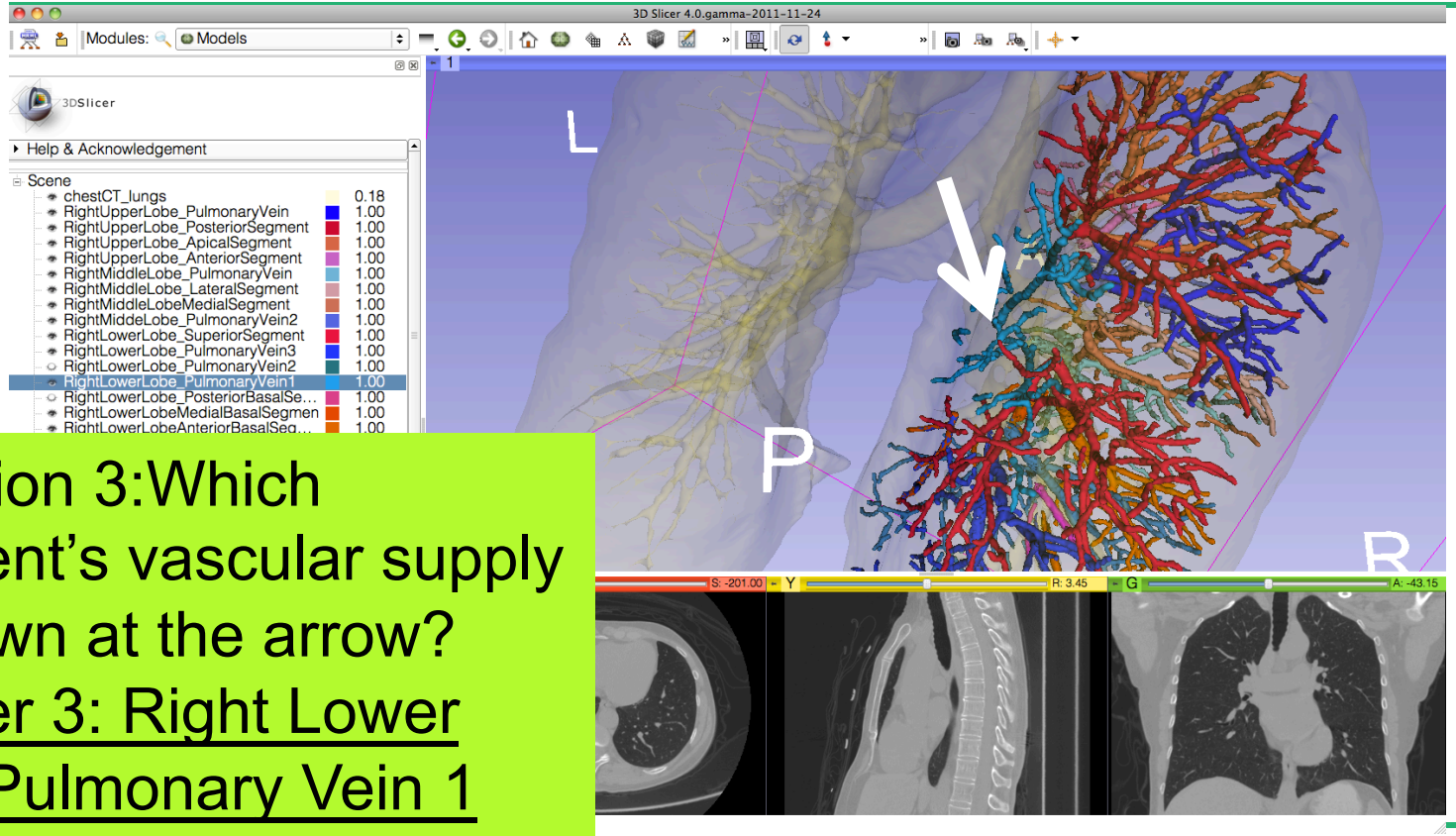
Lung Segments – Question 3



Question 3:Which segment's vascular supply is shown at the arrow?

Answer 3: Right Lower Lobe Pulmonary Vein 1

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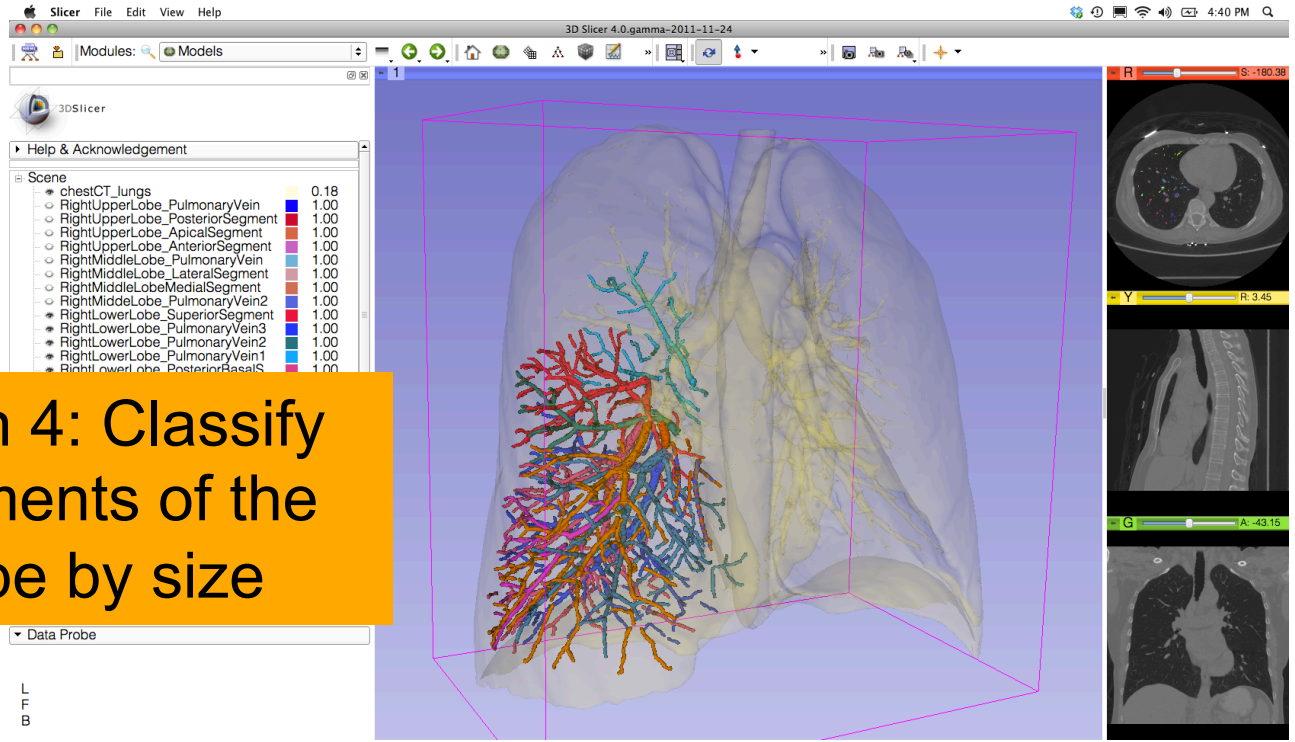
Lung Segments – Question 4



Question 4: Classify the segments of the lower lobe by size

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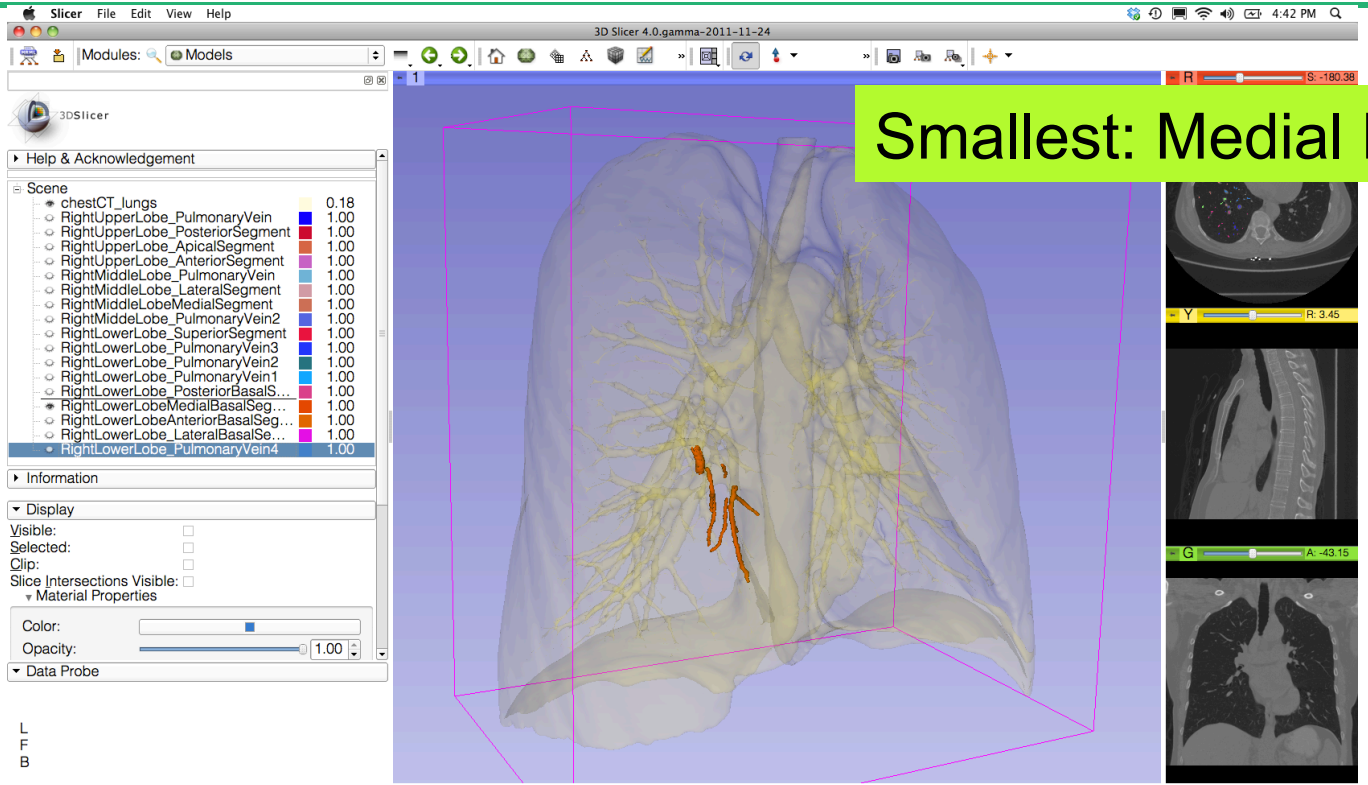
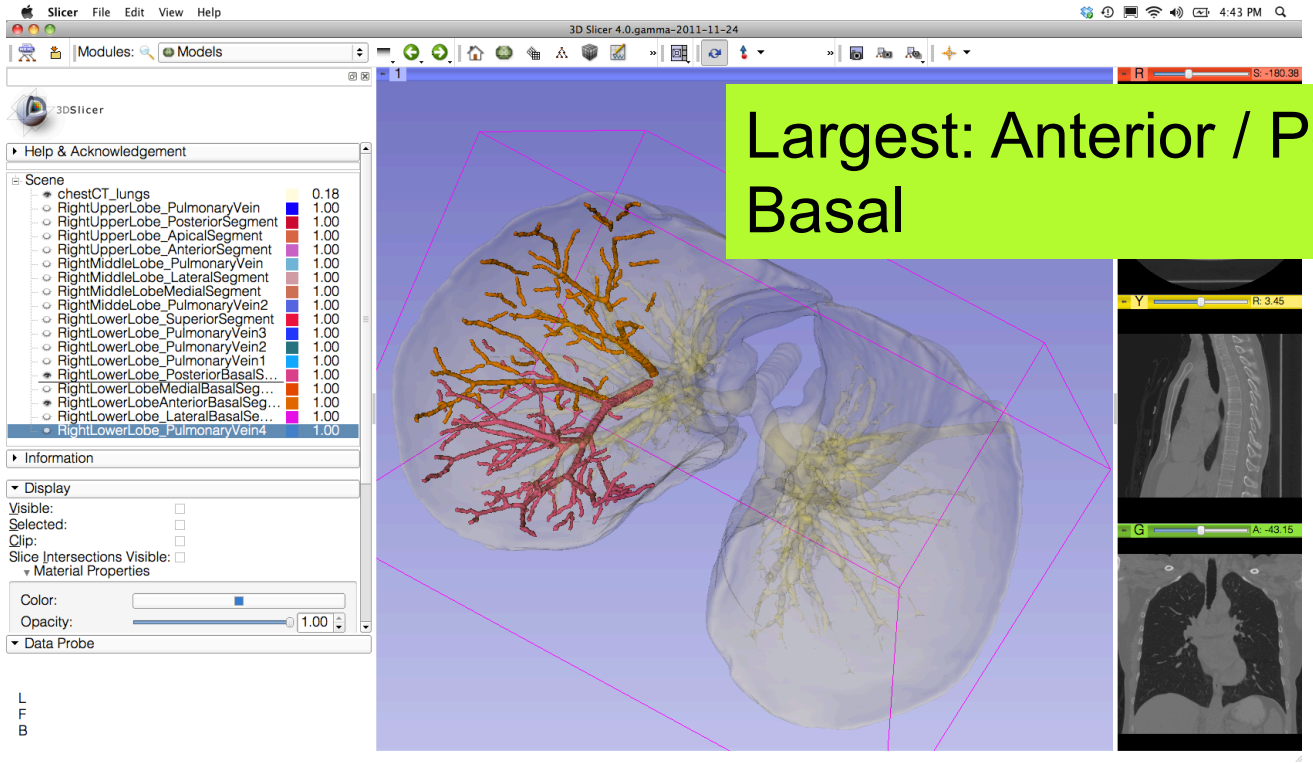
Lung Segments – Question 4



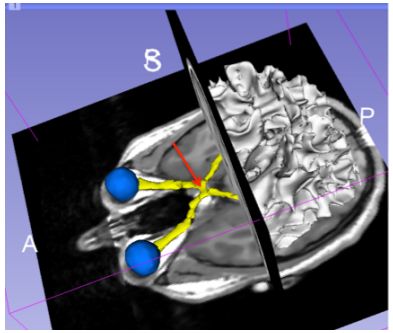
Smallest: Medial Basal

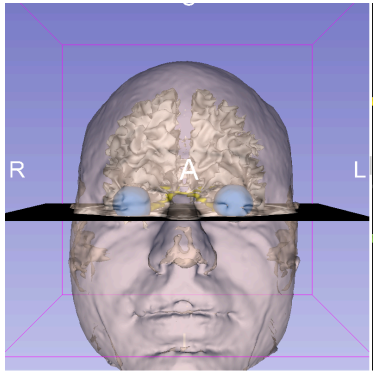
Lung Segments – Question 4

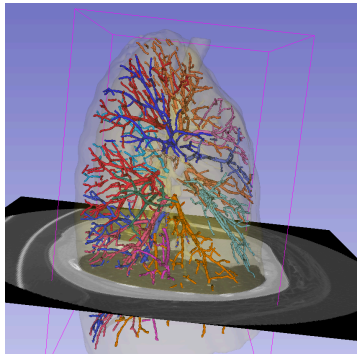


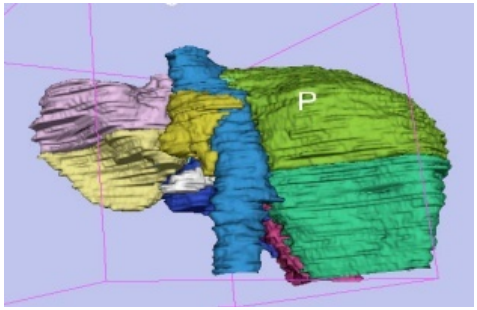
Largest: Anterior / Posterior Basal

3D Visualization of DICOM images









- Interactive user-interface to load and manipulate greyscale volumes, labelmaps and 3D models.
- User-defined 3D view of the anatomy
- 3D Open-source platform for Linux, Mac and Windows

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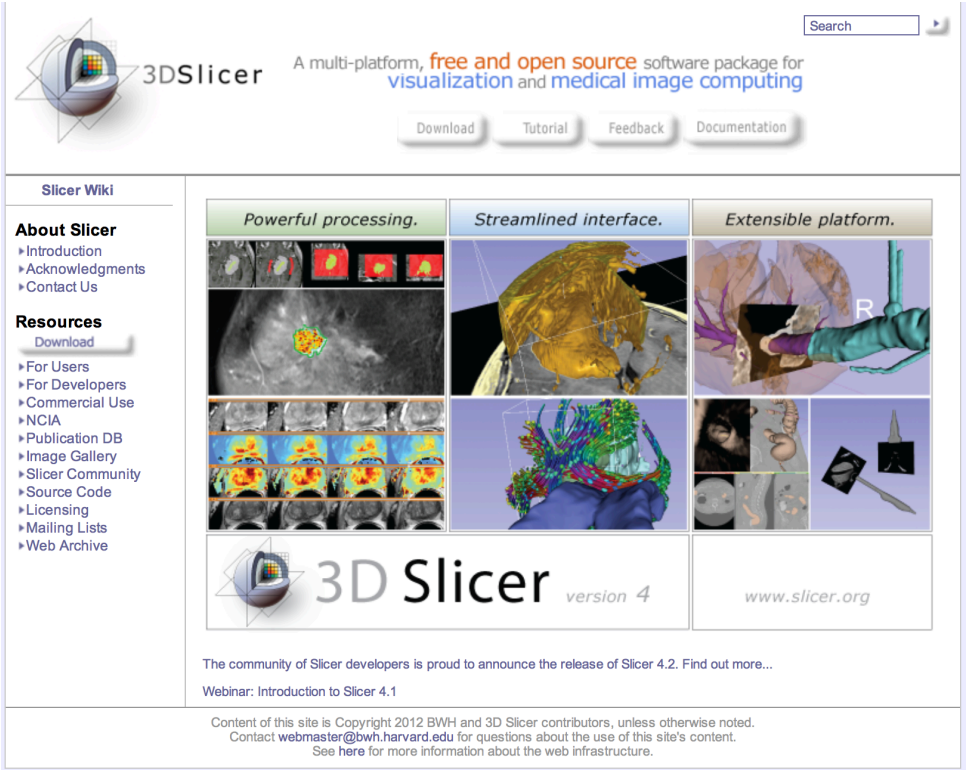
3DSlicer website



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3DSlicer at RSNA 2013

Quantitative Imaging Reading Room Exhibit QIRR 1028

- Sun. Dec.1-Fri. Dec.6, 8:00-6:00
- 3DSlicer: An Open Source Platform for Segmentation, Registration, Quantitative Imaging, and 3D Visualization of Multi-Modal Image Data.
- Sonia Pujol, PhD, Steve Pieper, PhD, Andriy Fedorov, PhD, Ron Kikinis, MD,

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Additional Related Hands-on courses

All courses are in this Advanced Imaging Classroom: S401CD (except Monday when it is in S401AB)

Sunday 11:00 am – Quantitative Imaging for Medical Research and Practice

Sunday 4:00 pm – Structured Annotation and Image Markup (AIM) Template and Toolsets (ICIW12)

Monday 4:30 pm – Clinical Trials Software for Clinical Trials and Research (ICIW24)

Wed 10:30 am – Open Access Imaging Data Resources: NIH Cancer Imaging Archive (ICIA41)

Wed 12:30 pm – Correlating Imaging with Human Genomics (ICIA42)

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3DSlicer at RSNA

Sunday, December 1	Monday, December 2	Tuesday, December 3	Wednesday, December 4	Thursday, December 5	Friday, December 6
8:00am-11:00am: 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**8:00am-11:00am:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**8:00am-11:00am:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**8:00am-12:15pm:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**8:00am-12:15pm:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**8:00am-12:45pm:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.
11:00am-12:30pm: RSNA Refresher Course: **"Quantitative Medical Imaging for Clinical Research and Practice: Hands-on Workshop."** **Sonia Pujol, Katarzyna Macura, Ron Kikinis** Room S401CD.	**12:30pm-1:30pm:** Meet-The-Experts Session, 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	**12:30pm-2:00pm:** RSNA Refresher Course: **"3D Interactive Visualization of DICOM Images for Radiology Applications: Hands-on Workshop."** **Sonia Pujol, Kitt Shaffer, Ron Kikinis** Room S401CD.	**1:30pm-6:00pm:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center, Hall E, Exhibit LL-QRR3007.	**12:30pm-1:30pm:** 3D Slicer Exhibit: **Quantitative Imaging Reading Room.** Lakeside Learning Center Hall E, Exhibit LL-QRR3007.	
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Questions: spujol@bwh.harvard.edu

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Marianna Jakab, Surgical Planning Laboratory, Brigham and Women's Hospital

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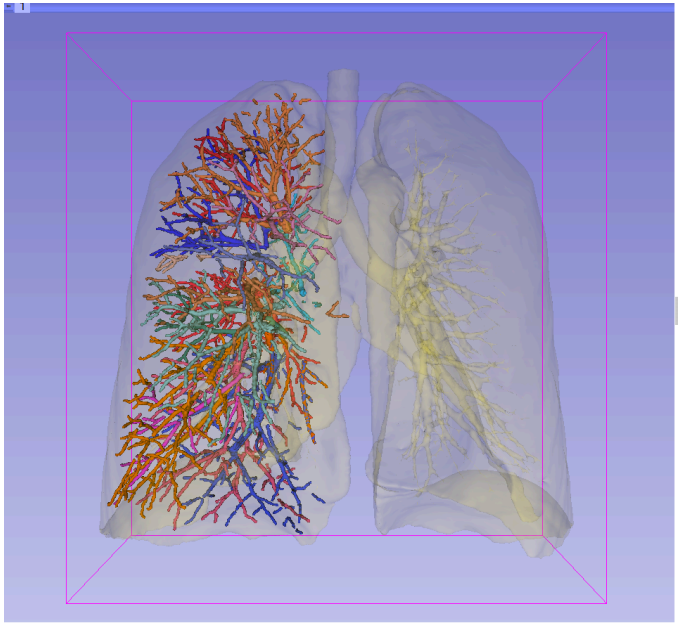

www.slicer.org

www.na-mic.org

Questions and comments: spujol@bwh.harvard.edu

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