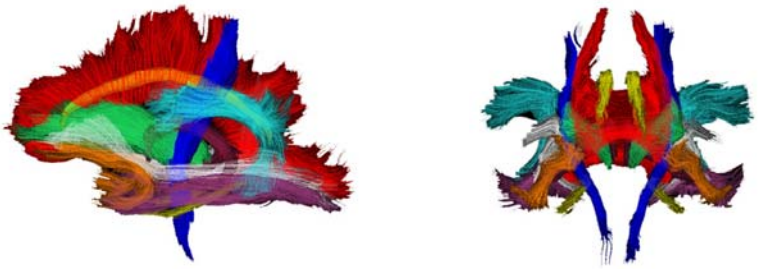
MMIL DTI Tractography Manual
resDTI/iso Methods (2008)



All fiber tracts were reconstructed in *DTI Studio* using the techniques described below. The basic operations follow Susumu Mori's 2-ROI approach, with the addition of subsequent multiple 'NOT' ROIs to remove extraneous ("stray") fibers that are not a part of the pathway. The locations of these 'NOT' ROIs are chosen based on anatomical references and research studies on white matter pathways, and vary from brain to brain. The purpose of this method is to reliably reconstruct anatomically accurate fiber bundles with a focus on the core, or body, of the fiber bundle.

Many fibers that are not a part of the fiber bundle of interest may be included in the 2-ROI approach, therefore these 'NOT' ROIs are applied.

The following atlas is a useful reference for brain anatomy in FA color maps:

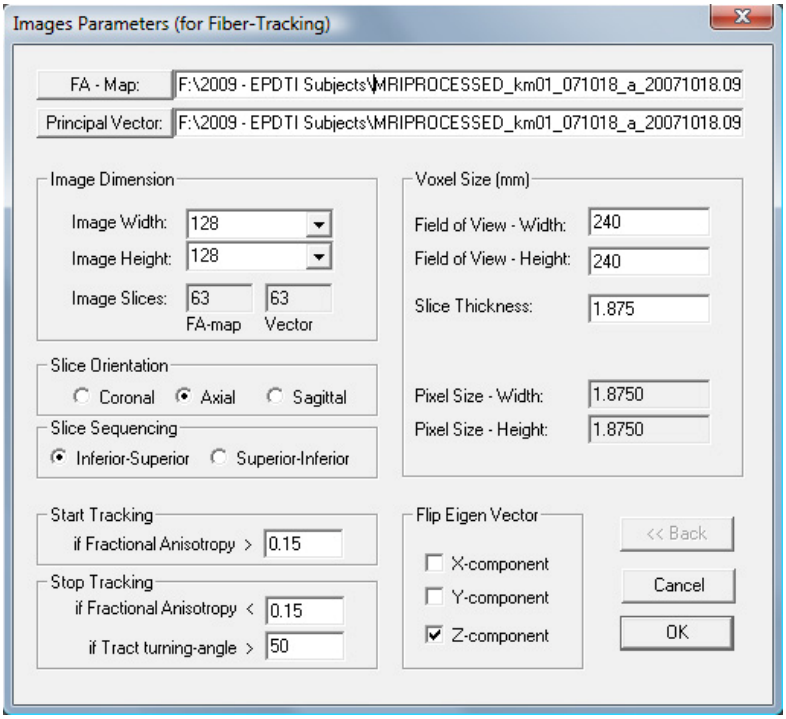
Mori, S., Wakana, S., Nagae-Poetscher, L.M., & van Zijl, P.C.M. (2005). *MRI Atlas of Human White Matter*. Amsterdam, Netherlands: Elsevier B.V.

General guidelines:

- **Visualization.** To better visualize anatomical structures that are obscured by the fibers shown on the 2D images, uncheck the box next to '*Show fibers on 2D images*' on the '*Fiber*' tab.
- **Size of second ROI.** When selecting the second of two ROIs as an 'AND' operation, the size of the ROI does not necessarily need to be precise; as long as the visualized fibers are within the ROI, those are the only fibers that are selected.
- **Location of second ROI.** When selecting the second of two ROIs, if the fibers are not present on the slice of interest, move proximally toward the slice of the first ROI until the fibers are visible and select these fibers as the second ROI.
- **ROI drawing guides.** Since each image plane shows the slice markers of the two other planes, it may be helpful to use these slice markers as guides to drawing an ROI. For example, in ROI#1 of the inferior longitudinal fasciculus (ilf), move the axial plane to mark the border of the parietal-occipital sulcus (pos), and select the ROI on the coronal slice inferior to axial slice marker.
- **Piece-wise removal of "stray" fibers using 'NOT' ROIs.** A single 'NOT' ROI may not remove all fibers passing through the ROI, therefore additional 'NOT' ROIs may be needed on adjacent slices. To remove these fibers, first apply the 'NOT' ROI at the distal end of the fiber, then move to adjacent proximal slices, removing the fiber in a piecewise manner from its termination point towards the body of the fiber bundle until the "stray" fiber is no longer a part of the bundle.
- **Fibers in meninges or CSF.** Always remove fibers that extend beyond the pial surface into the meningeal space using piecewise 'NOT' ROIs as described above. Similarly, always remove fibers that are visualized in the CSF space.
- **Looping fibers.** Always remove fibers that loop back in the direction from which they originated (180° turn) using piecewise 'NOT' ROIs as described above until the loop is removed.
- **Short fibers.** Always remove short fibers that do not fully project between the two ROIs.

Loading data, setup, and saving fibers:

1. Download and open *DTI Studio*.
2. Click on the *'File'* menu and select *'Fiber Tracking'*.
3. In the *Image Parameters* window, click on *'FA – Map'*, then browse for and select the FA map file. At the MMIL, this file is located in *~/MRIPROCESSED_*/DTcalc/DTI3_ecc_reg_mc_B0uw_gruw_iso_DT_FA.dat*.
   Note: File may also be called *DTI3_ecc_reg_mc_B0uw_gruw_resDTI_DT_FA.dat*.
4. In the *Image Parameters* window, click on *'Principal Vector'*, then browse for and select the V0 file. At the MMIL, this file is located in *~/MRIPROCESSED_*/DTcalc/DTI3_ecc_reg_mc_B0uw_gruw_iso_DT_V0.dat*.
   Note: File may also be called *DTI3_ecc_reg_mc_B0uw_gruw_resDTI_DT_V0.dat*.
5. Ensure that the following parameters are used for every subject and every fiber bundle:



6. Click *'OK'*.
7. Expand the window to increase the visible area.
8. In the *Image* tab on the right side of the window: under *Orthoganonal Views,* click the zoom in button ('+') twice; under *Image Processing*, click on *'Color Map'*. In the window that pops up, select the image in each of the two columns, and click *'OK'*.
9. In the *Fiber* tab on the right side of the window: under *Fiber Display*, check the box next to *'Show fibers on 2d images'*; under *Fiber Selection*, check the box next to *'ROI-Drawing Enable'*.
10. *DTIStudio* is ready for fiber tracking. In the *Fiber* tab, under *ROI Shape*, select the desired tool (often use the *'Poly'*), and under *ROI Operation*, select the desired operation.
11. Follow the steps below to reconstruct each of the fiber bundles in each of the two brain hemispheres.
12. When the reconstruction for an individual fiber bundle is complete, save the fiber. In the *Fiber* tab, under *Fiber Tracking*, click the *Save* button. In the prompt, select *'Save selected fibers'* and click *'OK'*. Navigate to the *~/MRIPROCESSED_*/DTIStudio_fiber_paths* directory (and if it doesn't exist, create the folder) and save exactly as *'Fiber_###_path.dat'* with the *###* corresponding to the Fiber Legend for MMIL DTI processing (page 4). The most recent version of the Legend is located in */home/epiproj/MetaData/StudyInfo/EPDTI_Fiber_Legend.csv*.

- To load saved fiber files, go to the *Fiber* tab, and under *Fiber Tracking* click the *Load* button. In the prompt to *Add new fibers to current ones?*, click *'No'*.

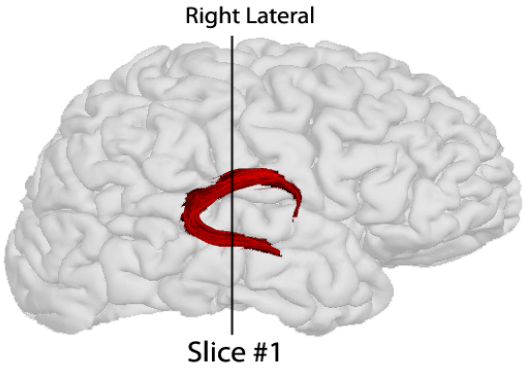
Table of Contents for Fiber Reconstruction

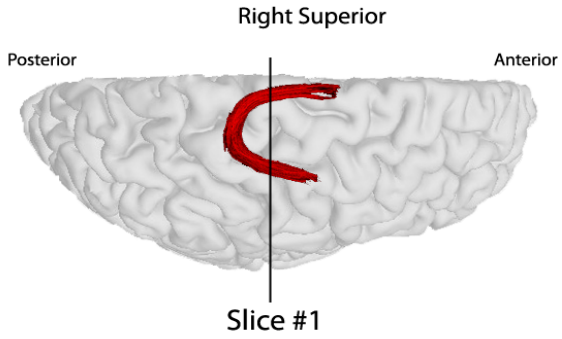
Fiber Legend for Saving Reconstructed Fibers

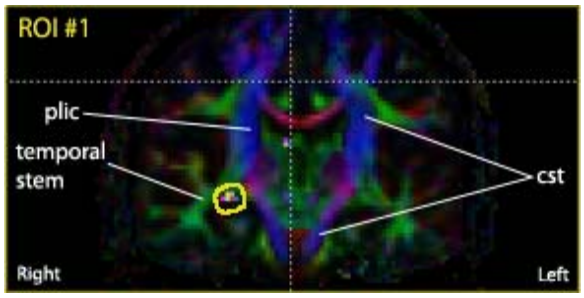
Fiber Number	Fiber Name	Long Name
101	R Fx	Right Fornix
102	L Fx	Left Fornix
103	R CgC	Right Cingulum (Cingulate)
104	L CgC	Left Cingulum (Cingulate)
105	R CgH	Right Cingulum (Parahippocampal)
106	L CgH	Left Cingulum (Parahippocampal)
107	R CST	Right Corticospinal Tract
108	L CST	Left Corticospinal Tract
109	R ATR	Right Anterior Thalamic Radiation
110	L ATR	Left Anterior Thalamic Radiation
115	R Unc	Right Uncinate
116	L Unc	Left Uncinate
117	R ILF	Right Inferior Longitudinal Fasiculus
118	L ILF	Left Inferior Longitudinal Fasiculus
119	R IFO	Right Inferior Fronto-Occipital Fasiculus
120	L IFO	Left Inferior Fronto-Occipital Fasiculus
121	F-maj	Forceps Major
122	F-min	Forceps Minor
123	CC	Corpus Callosum
133	R SLF	Right Superior Longitudinal Fasiculus
134	L SLF	Left Superior Longitudinal Fasiculus
135	R tSLF	Right Temporal Superior Longitudinal Fasiculus
136	L tSLF	Left Temporal Superior Longitudinal Fasiculus
137	R pSLF	Right Parietal Superior Longitudinal Fasiculus
138	L pSLF	Left Parietal Superior Longitudinal Fasiculus

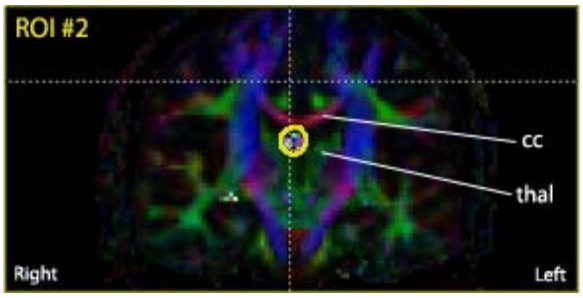
Fornix (Fx)

C-shaped bundle of fibers that originate in the hippocampus, loop around the thalamus, and terminate in the septal area of the hypothalamus.



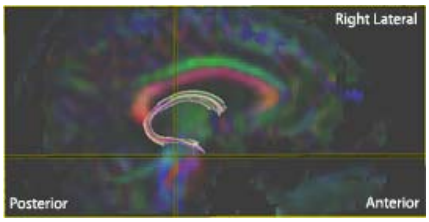


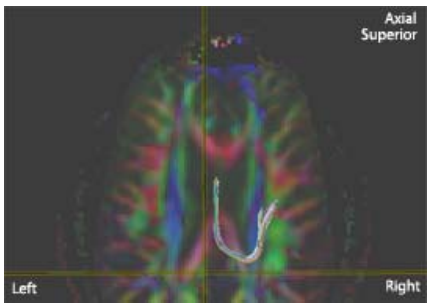


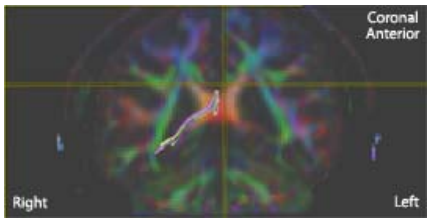


1. **ROI #1:** Identify the most posterior coronal slice in which the corticospinal tract (cst) can be seen continuously from superior cortex to brainstem. One coronal slice posterior to this section is chosen at Slice #1; draw an 'OR' ROI around the fimbria of the fornix (a bright green focal intensity), lateral to the posterior limb of the internal capsule (plic) and medial to the temporal stem.
2. **ROI #2:** On the same coronal section (Slice #1), draw an 'AND' ROI around the body of the fornix, at the mid-sagittal line inferior to the corpus callosum (cc) and medial to the thalamus (thal).
3. **'NOT' ROIs:**
    a. Remove fibers extending to the contralateral hemisphere in an off-mid-sagittal plane.
    b. Remove fibers extending anteriorly and superiorly from the body of the fornix.
    c. Remove fibers extending inferiorly and posteriorly from the anterior column/pillar of the fornix.
    d. Remove fibers extending anteriorly from the fimbria of the fornix beyond the amygdala to the temporal lobe.
    e. Remove fibers extending through the thalamus (thal).

Final Fiber Bundle:





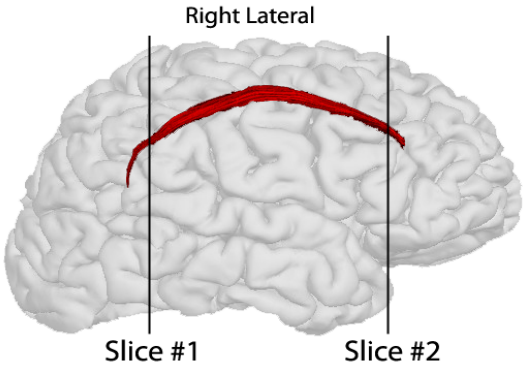


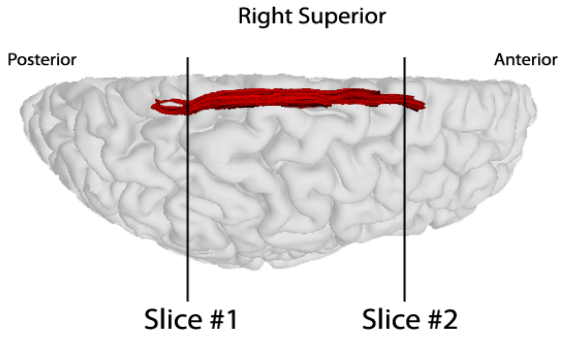
Cingulum (Cg)

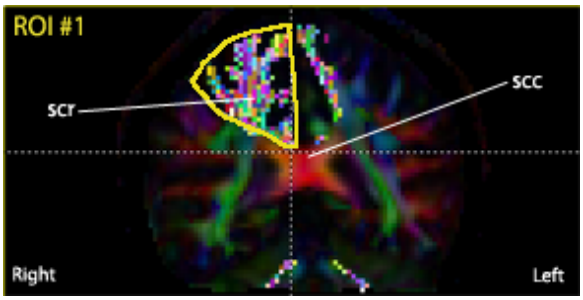
C-shaped bundle of long association fibers that course longitudinally within the cingulate gyrus, arcing inferiorly around the splenium of the corpus collosum, and into the parahippocampal gyrus, terminating in the entorhinal cortex.

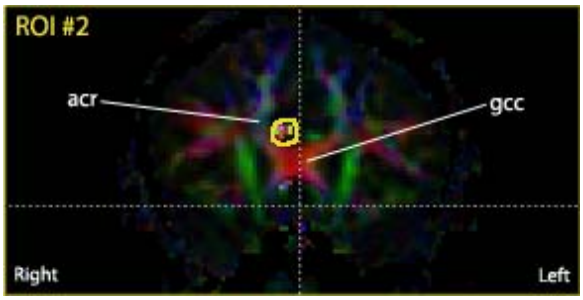
Note: Because of its narrow, arcing shape, it is difficult to reconstruct the cingulum as a single, continuous fiber bundle; therefore it is divided into two parts.

Cingulum, cingulate gyrus part (CgC)



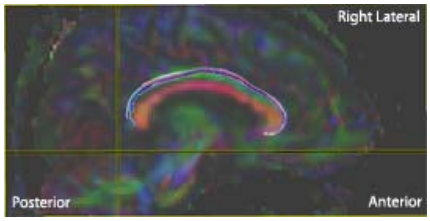


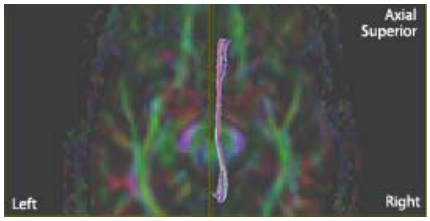


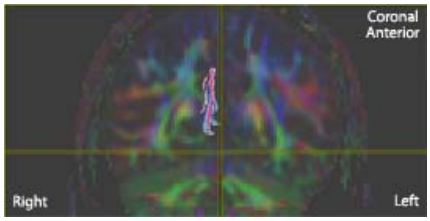


1. **ROI #1:** A coronal slice at the level of the mid-splenium of the corpus callosum (scc) is chosen at Slice #1; draw an 'OR' ROI around the posterior part of the cingulum (a bright green focal intensity), superior to the corpus callosum (cc) including the main branch of the superior corona radiata (scr).
2. **ROI #2:** A coronal slice at the level of the mid-genu of the corpus callosum (gcc) is chosen at Slice #2; draw an 'AND' ROI around the anterior part of the cingulum, superior to the corpus callosum (cc) and medial to the anterior corona radiata (acr).
3. **'NOT' ROIs:**
    a. Remove fibers extending to the contralateral hemisphere at the mid-sagittal line.
    b. Remove fibers extending superiorly from the length of the cingulum to superior frontal and central cortical regions.
    c. Remove fibers extending anteriorly from the cingulum to the frontal lobe.
    d. Remove fibers extending inferiorly from the anterior part of the cingulum.
    e. Remove fibers extending posteriorly from the cingulum to the occipital and parietal lobes.

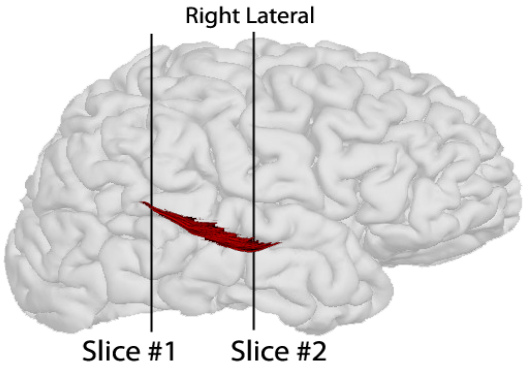
Final Fiber Bundle:

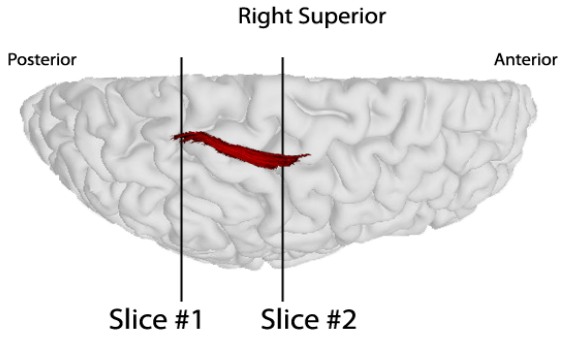


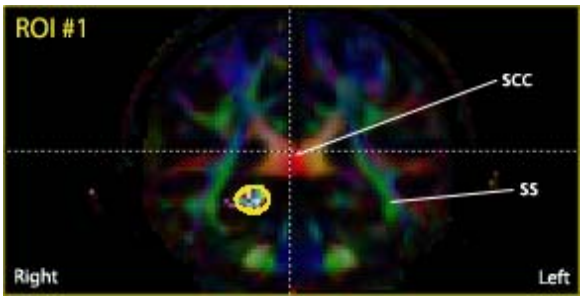


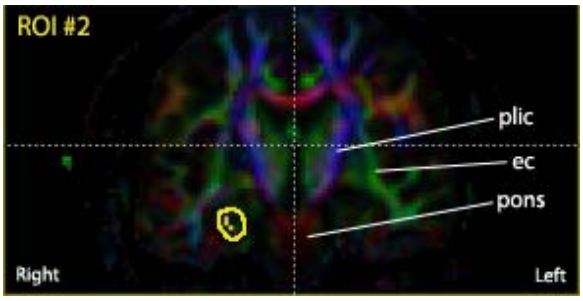


Cingulum,parahippocampal part (CgH)



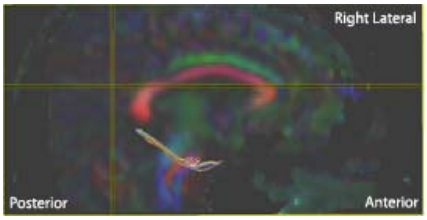


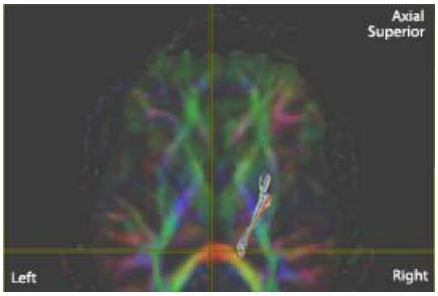


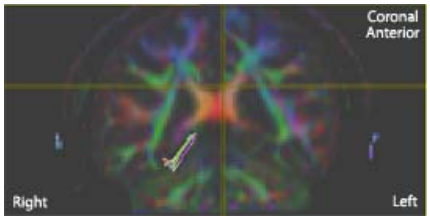


1. **ROI #1:** A coronal slice at the level of the mid-splenium of the corpus callosum (scc) is chosen at Slice #1; draw an 'OR' ROI around the posterior part of the cingulum (a bluish-green focal intensity) inferior to the corpus callosum (cc) and medial to the sagittal striatum (ss).
2. **ROI #2:** Identify the pons in a para-sagittal section. One coronal slice anterior to the pons is chosen at Slice #2; draw an 'AND' ROI around the parahippocampal part of the cingulum, inferior to the posterior limb of the internal capsule (plic) and external capsule (ec), and medial to the temporal lobe.
3. **'NOT' ROIs:**
    a. Remove fibers extending posteriorly to the parietal and occipital lobes.
    b. Remove fibers extending posteriorly and inferiorly from the anterior part of the cingulum.

Final Fiber Bundle:

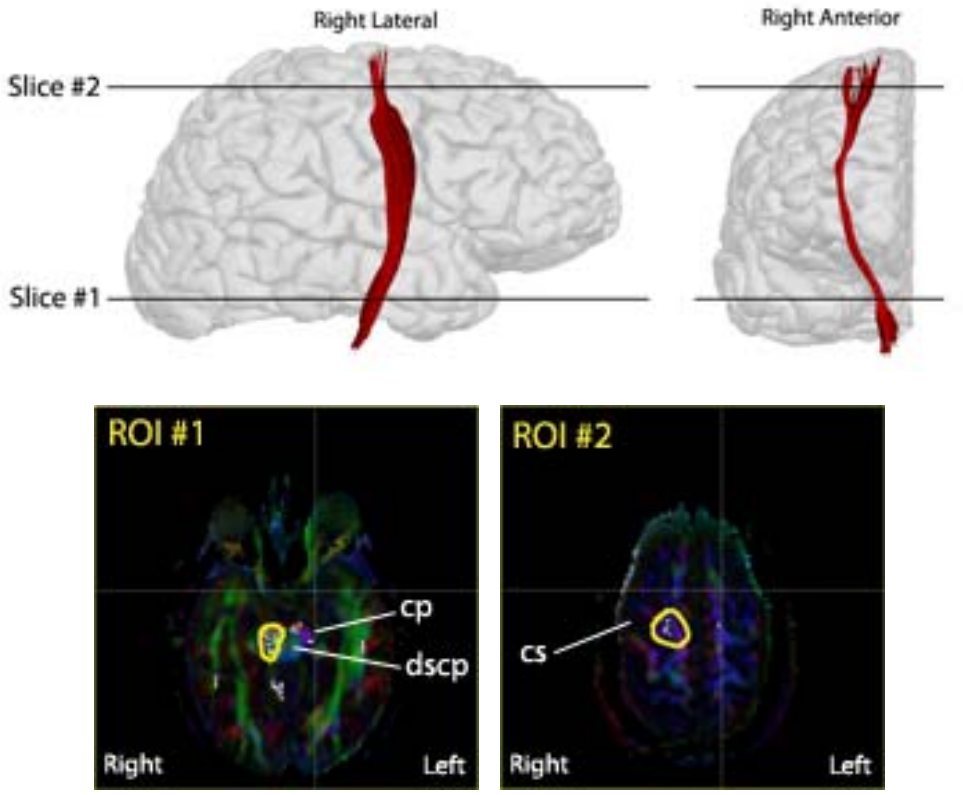






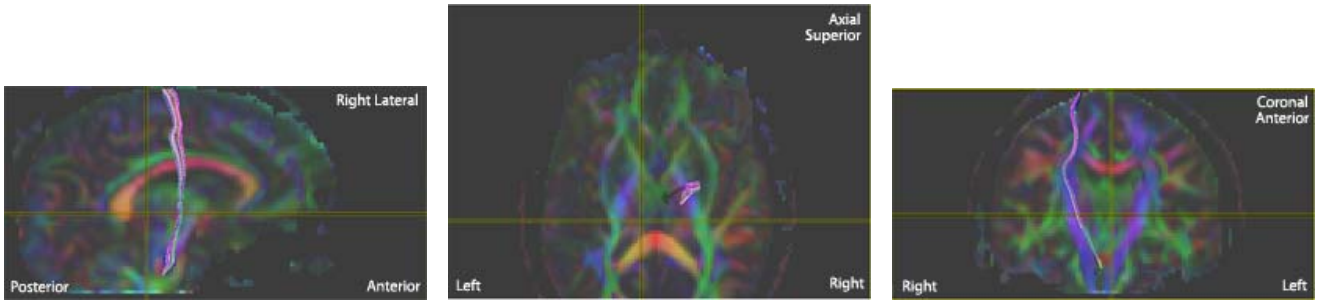
Corticospinal tract (CST)

Bundle of projection fibers that descend inferiorly from the motor cortex (M1) through the cerebral peduncle of the brainstem into the spinal cord.



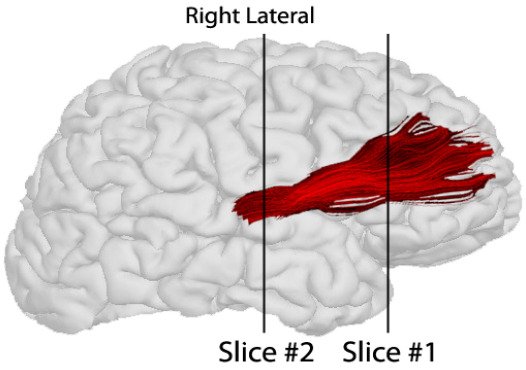
1. **ROI #1:** Identify the most superior axial slice in which the decussation of the superior cerebral peduncle (dscp) is visible (a bright red focal intensity); this axial slice is chosen at Slice #1. Draw an 'OR' ROI around the cerebral peduncle (cp), anterior and lateral to the point of decussation.
2. **ROI #2:** Identify the central sulcus (cs); it should be clearly discernable in the reconstruction result from *ROI #1*. The most inferior slice in which the cleavage of the central sulcus in the fiber bundle can be identified is chosen at Slice #2; draw an 'AND' ROI around those fibers in the primary motor cortex (M1), anterior to the central sulcus.
3. **'NOT' ROIs:**
    a. Remove fibers extending to the contralateral hemisphere at the mid-sagittal line.
    b. Remove fibers extending posteriorly from the corticospinal tract to the cerebellum.
    c. Remove fibers extending outside the boundaries of the cerebral peduncle in the brainstem.

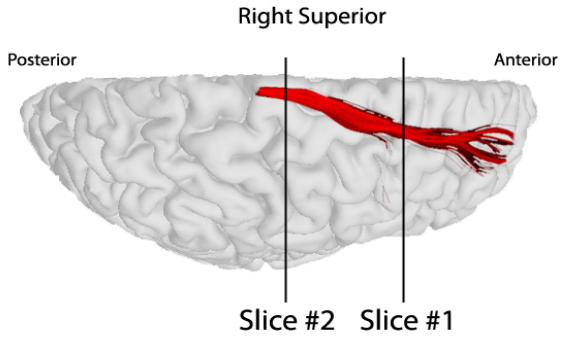
Final Fiber Bundle:

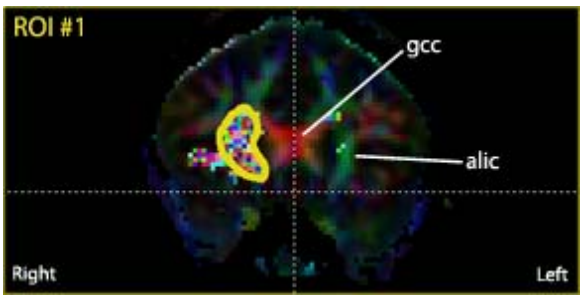


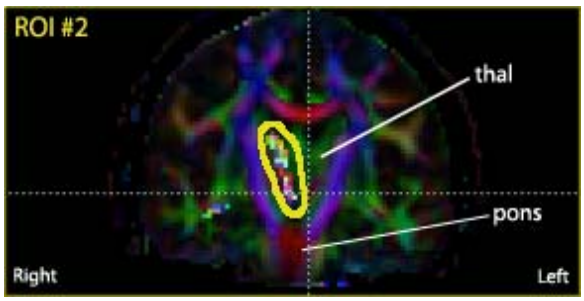
Anterior thalamic radiation (ATR)

Bundle of projection fibers from the anterior and medial thalamic nuclei that course through the anterior limb of the internal capsule and terminate in the cerebral cortex of the frontal lobe.



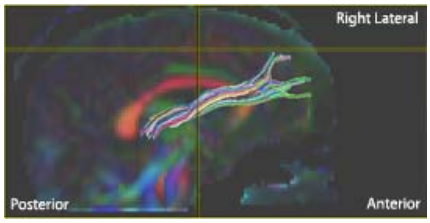


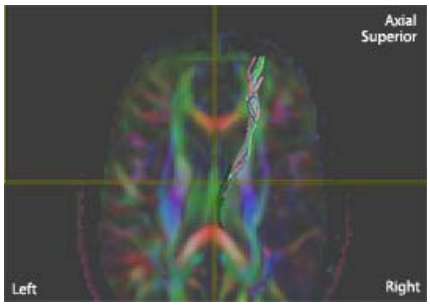


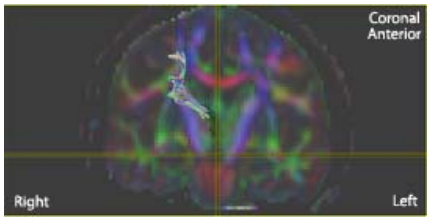


1. **ROI #1:** A coronal slice at the level of the mid-genu of the corpus callosum (gcc) is chosen at Slice #1; Draw an 'OR' ROI around the anterior limb of the internal capsule (alic).
2. **ROI #2:** Identify the pons in a para-sagittal section. A coronal slice at the anterior edge of the pons is chosen at Slice #2; draw an 'AND' ROI around the entire thalamus (thal).
3. **'NOT' ROIs:**
    a. Remove fibers extending to the contralateral hemisphere at the mid-sagittal line.
    b. Remove fibers extending inferiorly beyond the thalamus to the brainstem and cerebellum.
    c. Remove fibers extending posteriorly beyond the thalamus.
    d. Remove fibers extending superiorly to the parietal lobe (post-central regions).
    e. Remove fibers at the posterior end that do not terminate in the thalamus.

Final Fiber Bundle:

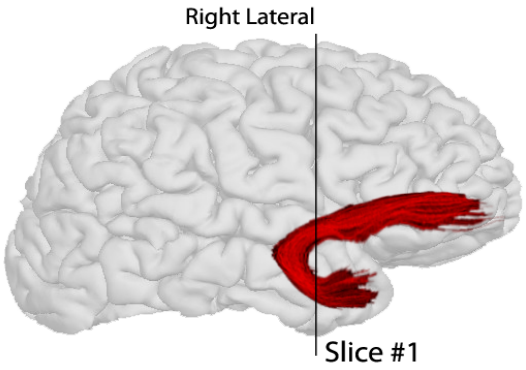


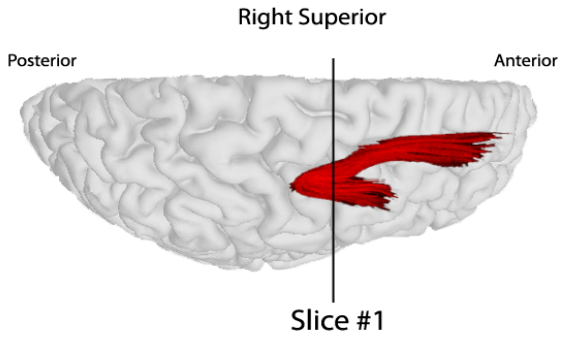


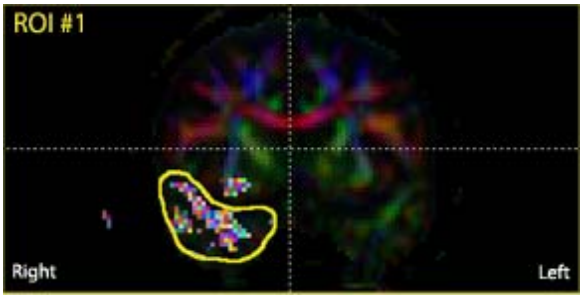


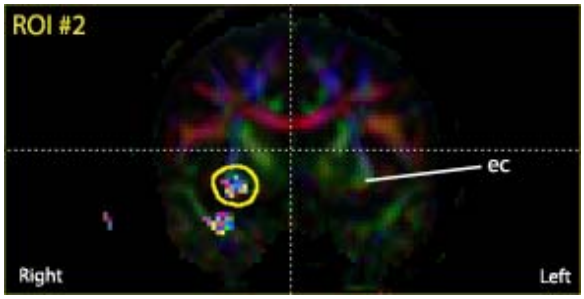
Uncinate (Unc)

C-shaped bundle of association fibers that arc through the lateral fissure, connecting the orbital cortex of the frontal lobe and the anterior temporal lobe.



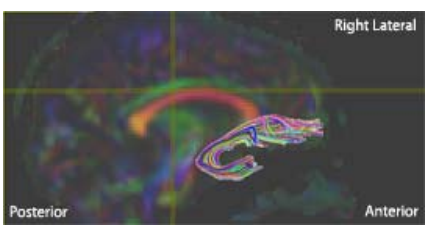


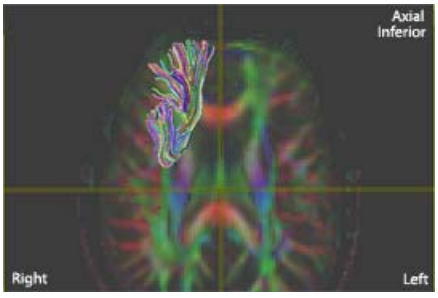


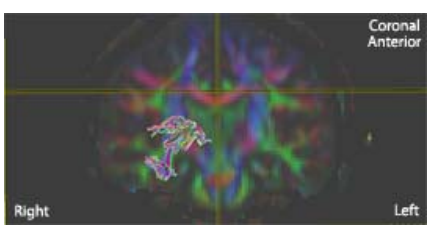


1. **ROI #1:** Identify the most posterior coronal slice in which the temporal lobe is visibly distinct from the frontal lobe; this coronal slice is chosen at Slice #1. Draw an 'OR' ROI around the entire temporal lobe. *This is the same ROI as ROI #2 of the inferior longitudinal fasciculus (ilf).*
2. **ROI #2:** On the same coronal section (Slice #1), draw an 'AND' ROI around the external capsule (ec).
3. **'NOT' ROIs:**
    a. Remove fibers extending posteriorly from the main bundle of the uncinate.
    b. Remove short fibers at the temporal stem that do not fully extend into the temporal and frontal lobes.

Final Fiber Bundle:

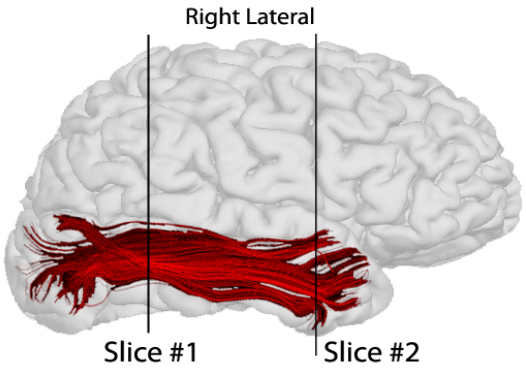


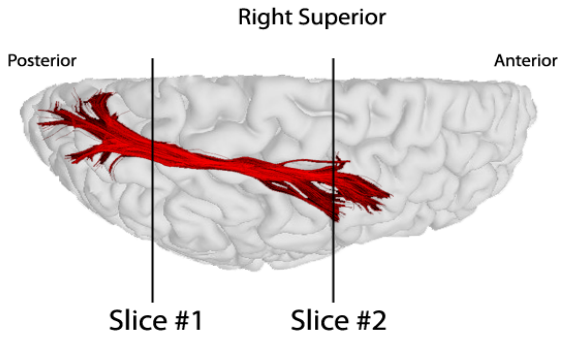


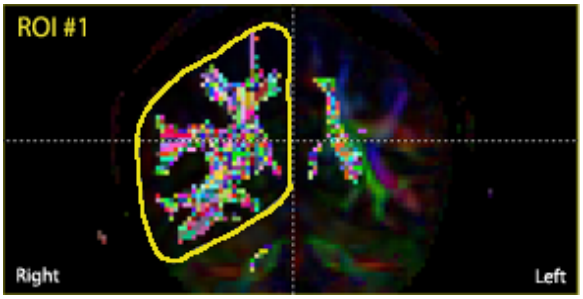


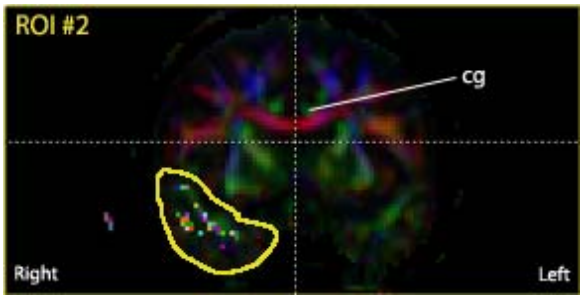
Inferior longitudinal fasciculus (ILF)

Bundle of long association fibers that course through the sagittal striatum (ss), connecting the occipital lobe and the temporal lobe.



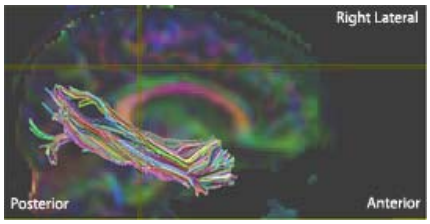


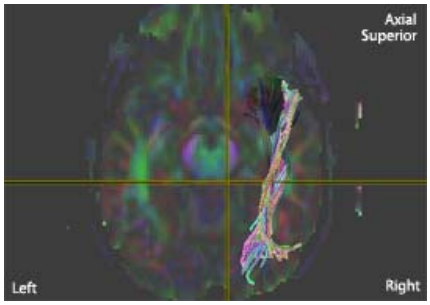


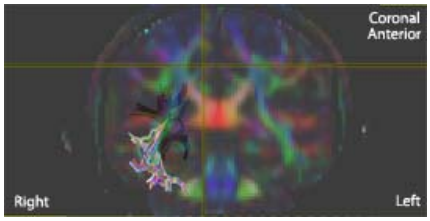


1. **ROI #1:** Identify the most posterior coronal slice in which the cingulum (cg) is visible; this coronal slice is chosen at Slice #1. Draw an 'OR' ROI around the entire hemisphere.
2. **ROI #2:** Identify the most posterior coronal slice in which the temporal lobe is visibly distinct from the frontal lobe; this coronal slice is chosen at Slice #2. Draw an 'AND' ROI around the entire temporal lobe. *This is the same ROI as ROI #1 of the uncinate (unc).*
3. **'NOT' ROIs:**
    a. Remove fibers extending the contralateral hemisphere at the mid-sagittal line.
    b. Remove fibers extending superiorly to the parietal lobe beyond the parietal-occipital sulcus (pos).
    c. Remove fibers extending anteriorly that terminate in the frontal lobe.

Final Fiber Bundle:

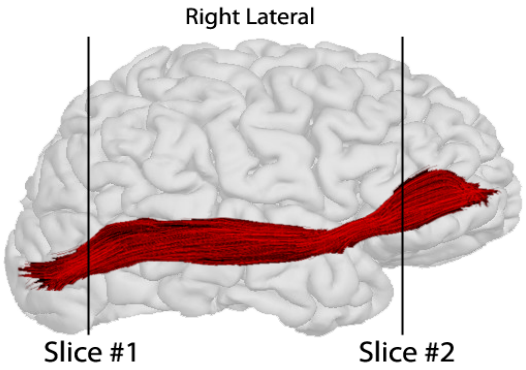


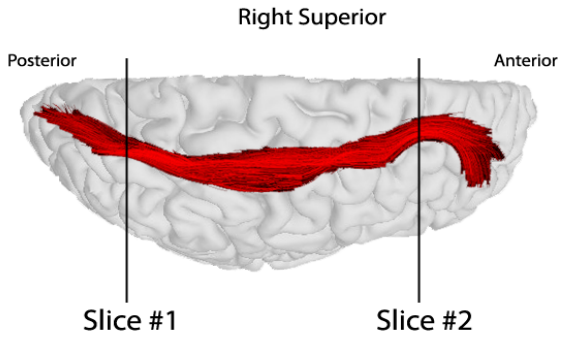


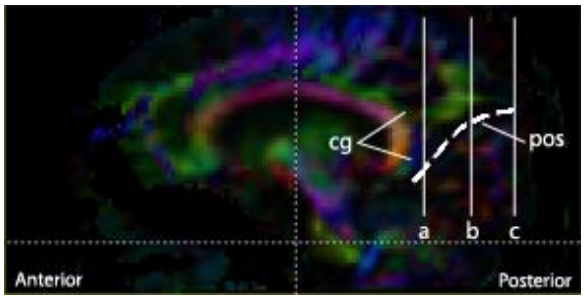


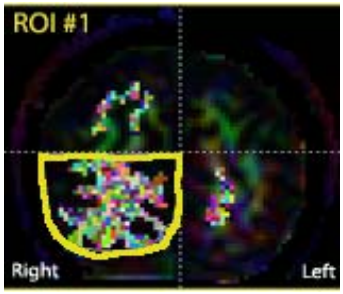
Inferior frontal occipital fasciculus (IFO)

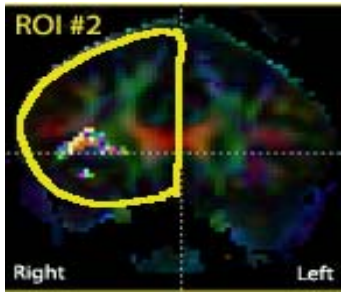
Bundle of long association fibers that course through the sagittal striatum (ss) and external capsule (ec), connecting the occipital lobe and the frontal lobe.





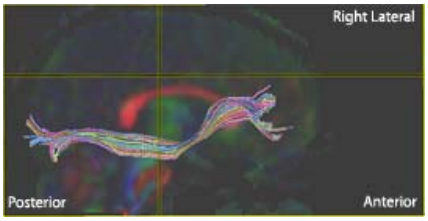


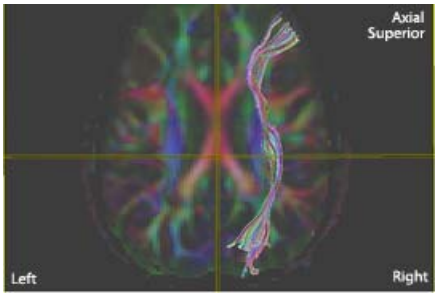


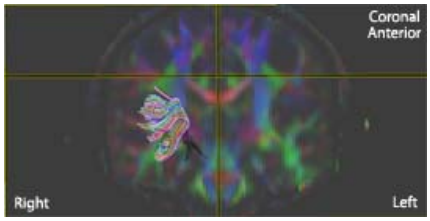


1. **ROI #1:** Identify the anterior-posterior midpoint in a coronal slice (Slice *b* above) between the posterior edge of the cingulum (cg) (Slice *a* above) and the posterior edge of the parietal-occipital sulcus (pos) (Slice *c* above); this coronal slice is chosen at Slice #1. Draw an 'OR' ROI around the occipital lobe, inferior to the parietal-occipital sulcus (pos). *This is the same ROI as in ROI #1 of the forceps major (Fmaj)*.
2. **ROI #2:** Identify the most anterior edge of the genu of the corpus callosum (gcc) in a coronal slice; this slice is chosen at Slice #2. Draw an 'AND' ROI around the entire ipsilateral hemisphere.
3. **'NOT' ROIs:**
    a. Remove fibers extending superiorly and posteriorly beyond the parietal-occipital sulcus (pos).
    b. Remove fibers extending through the thalamus.

Final Fiber Bundle:

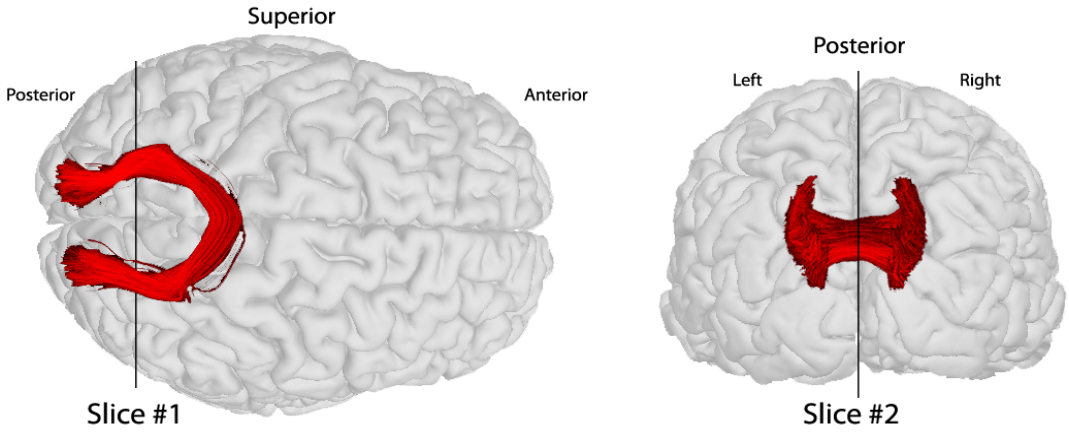


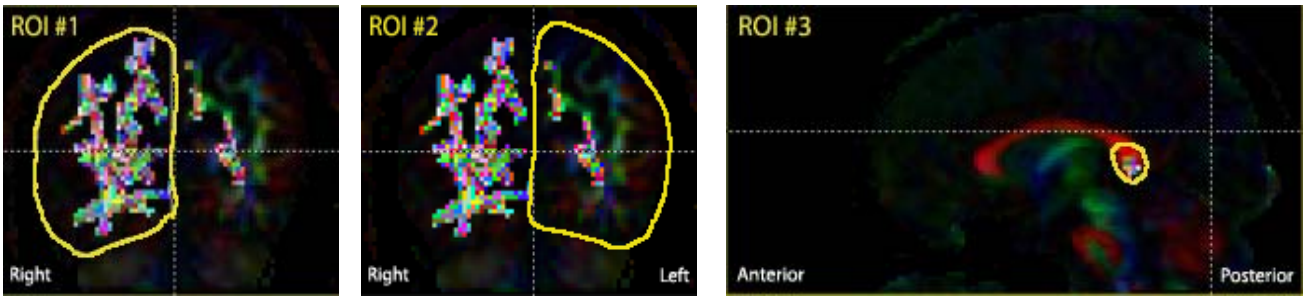




Forceps major (F-maj)

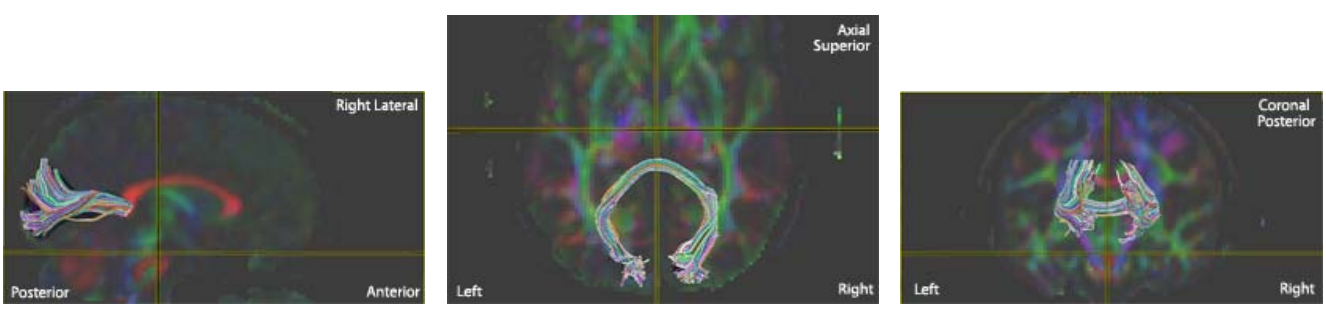
Bundle of callosal fibers that contralaterally connect the occipital lobes through the splenium of the corpus callosum.
Note: A third ROI is applied in order to remove extraneous fibers that do not pass through the splenium.





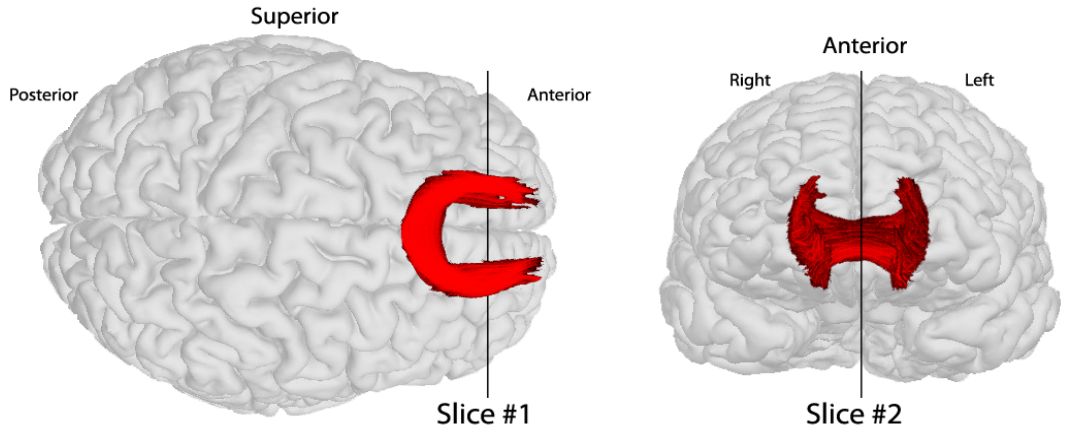
1. **ROI #1:** Identify the anterior-posterior midpoint in a coronal slice (Slice *b* of *ifo*) between the posterior edge of the cingulum (cg) (Slice *a* of *ifo*) and the posterior edge of the parietal-occipital sulcus (pos) (Slice *c* of *ifo*); this coronal slice is chosen at Slice #1. Draw an 'OR' ROI around the entire hemisphere. *This is the same ROI as in ROI #1 of the inferior frontal occipital fasciculus (ifo).*
2. **ROI #2:** On the same coronal section (Slice #1), draw an 'AND' ROI around the entire contralateral hemisphere.
3. **ROI #3:** Identify the splenium of the corpus callosum (scc) in a mid-sagittal slice; this sagittal slice is chosen at Slice #2. Draw an 'AND' ROI around the splenium.
4. **'NOT' ROIs:**
    a. Remove fibers extending superiorly beyond the parietal-occipital sulcus (pos).
    b. Remove fibers that extend anteriorly beyond the splenium.
    c. Remove fibers that do not fully bilaterally project; fibers may terminate at the mid-sagittal line.

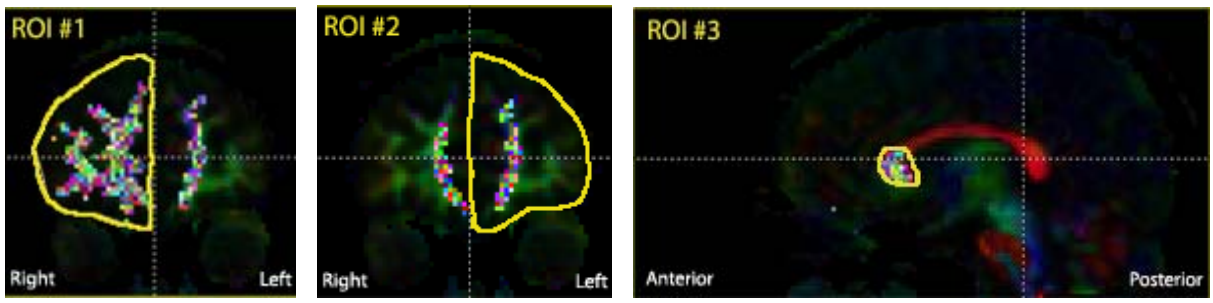
Final Fiber Bundle:



Forceps minor (F-min)

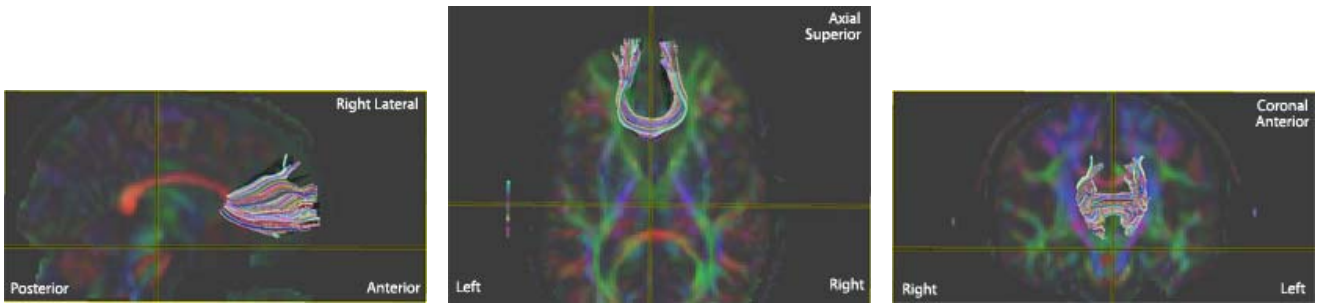
Bundle of callosal fibers that contralaterally connect the frontal lobes through the genu of the corpus callosum.
Note: A third ROI is applied in order to remove extraneous fibers that do not pass through the genu.





1. **ROI #1:** Identify the anterior-posterior midpoint on a coronal slice between the anterior edge of the genu of the corpus callosum (gcc) and the frontal pole; this coronal slice is chosen at Slice #1. Draw an 'OR' ROI around the entire hemisphere.
2. **ROI #2:** On the same coronal section (Slice #1), draw an 'AND' ROI around the entire contralateral hemisphere.
3. **ROI #3:** Identify the genu of the corpus callosum (gcc) in a mid-sagittal slice; this sagittal slice is chosen at Slice #2. Draw an 'AND' ROI around the genu.
4. **'NOT' ROIs:**
    a. Remove fibers extending posteriorly beyond the genu.
    b. Remove fibers that do not fully bilaterally project; fibers may terminate at the mid-sagittal line.

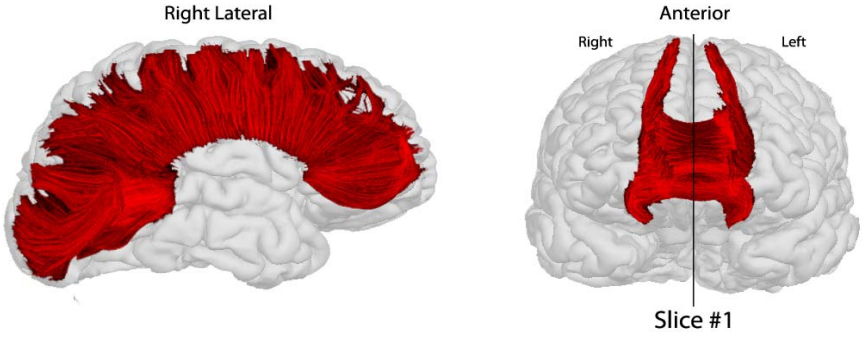
Final Fiber Bundle:

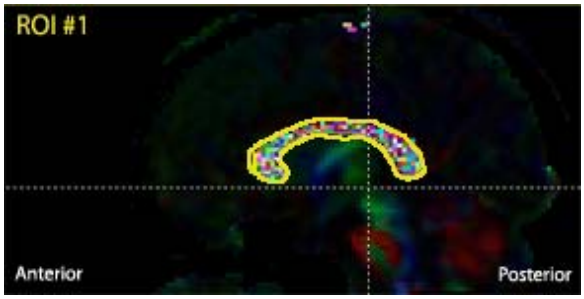


Corpus callosum (CC)

Large bundle of commissural fibers that course through the interhemispheric fissure, connecting the left and right hemispheres.

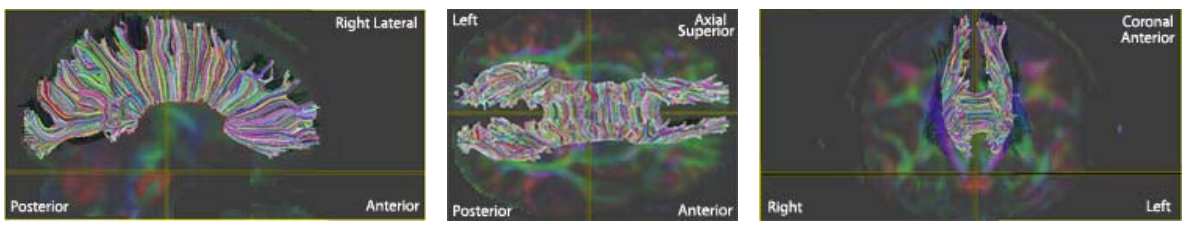
Note: Only one ROI is applied to reconstruct the entire corpus callosum (cc); it is important to apply many 'NOT' ROIs to remove fibers that are not a part of the corpus callosum.





1. **ROI #1:** Identify the mid-sagittal slice; this saggital slice is chosen at Slice #1. Draw an 'OR' ROI around the entire corpus callosum (cc).
2. **'NOT' ROIs:**
    a. Remove fibers extending through the external capsule (ec), striatum, internal capsule (ic) and the thalamus (thal).
    b. Remove fibers extending anteriorly-posteriorly just superior to the corpus callosum (cc) (e.g. cingulum (cg)).
    c. Remove fibers that do not fully bilaterally project; fibers may terminate at the mid-sagittal line.
    d. Remove fibers that are a part of the tapetum.

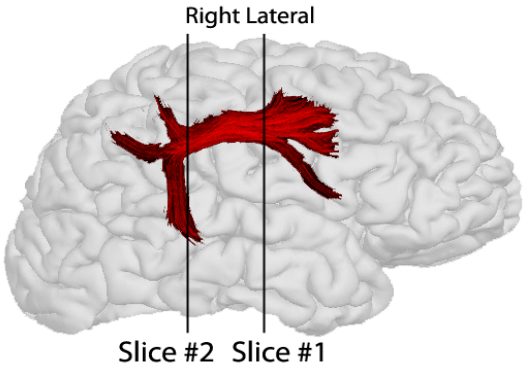
Final Fiber Bundle:

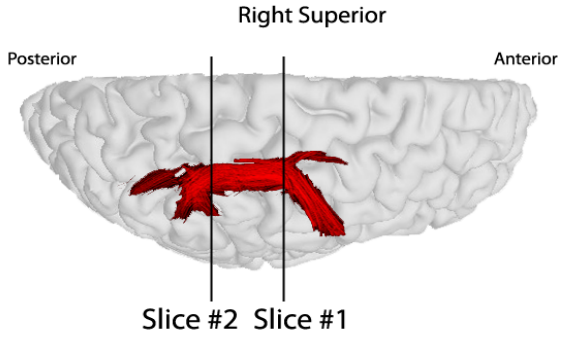


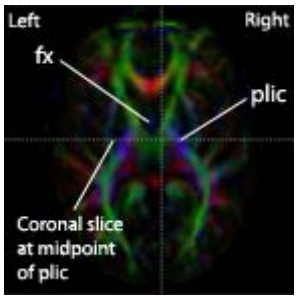
Superior longitudinal fasciculus (SLF)

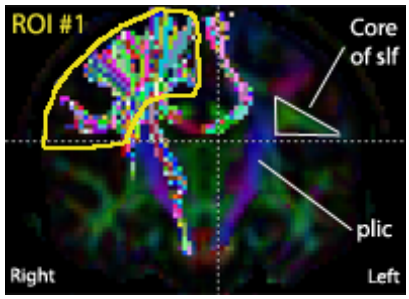
Bundle of long association fibers that course alongside the superior edge of the insula, connecting the frontal, temporal, parietal, and occipital lobes (also known as the arcuate fasciculus).

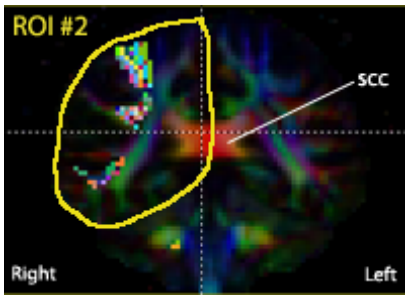
Note: To reconstruct and separate the main components of the superior longitudinal fasciculus, it is divided into three parts.







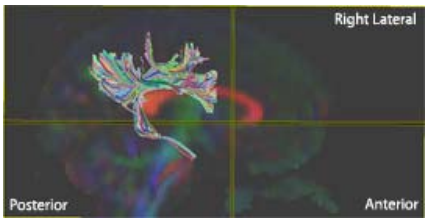


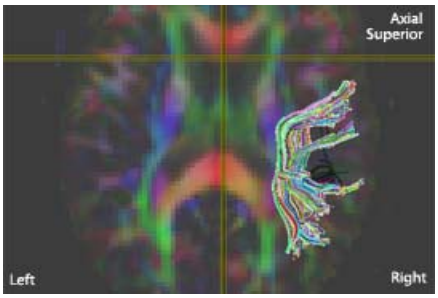


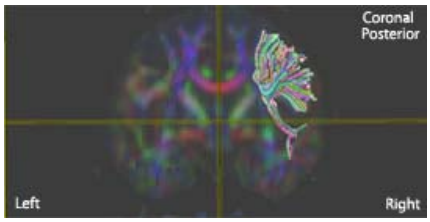
Superior longitudinal fasciculus (slf)

1. **ROI #1:** Identify the most inferior axial slice in which the fornix (fx) can be seen as a single structure (bright green intensity). On the same axial slice, identify the anterior-posterior midpoint of the posterior limb of the internal capsule (plic); a coronal slice at this midpoint is chosen at Slice #1. The core of the superior longitudinal fasciculus is visible as a bright green triangular intensity in the superolateral area, just lateral to the posterior limb of the internal capsule. Draw an 'OR' ROI around this core including all superior and lateral gyri coming from this core.
2. **ROI #2:** Identify the midpoint of the splenium of the corpus callosum (scc) in a coronal slice; this slice is chosen at Slice #2. Draw an 'AND' ROI around the entire ipsilateral hemisphere.
3. **'NOT' ROIs:**
    a. Remove fibers extending into the external capsule (ec).
    b. Remove fibers extending inferiorly through the brainstem.
    c. Remove fibers extending through the cingulum (cgc).

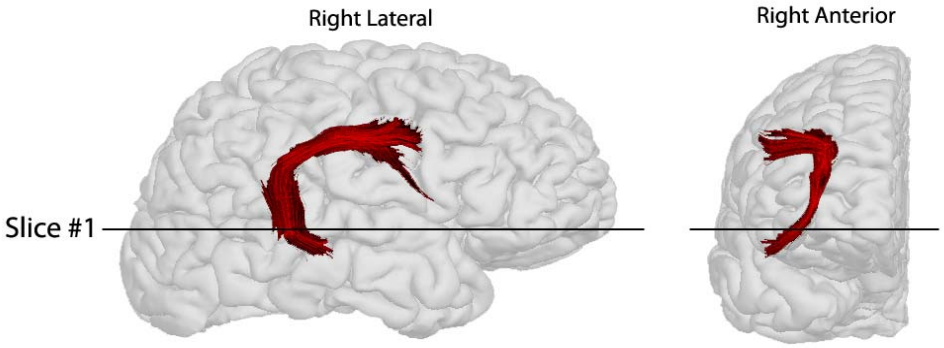
Final Fiber Bundle:

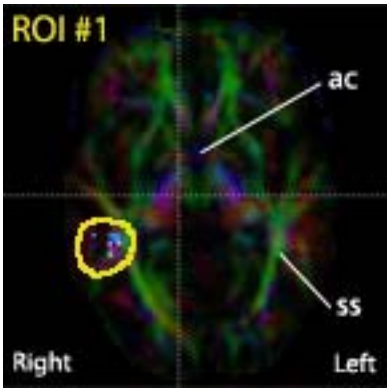






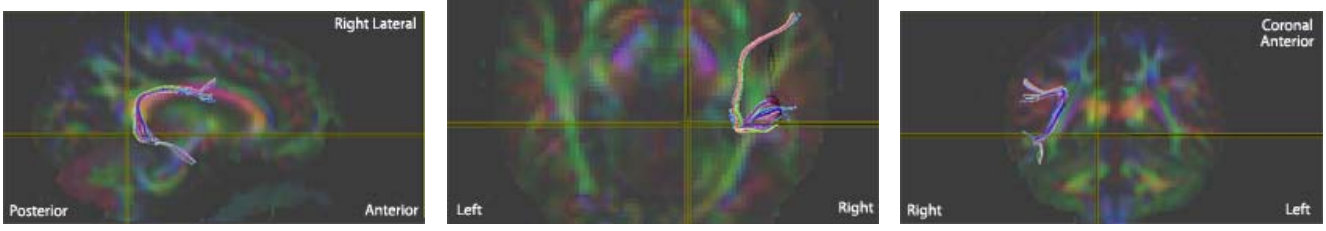
Superior longitudinal fasciculus, temporal part (tSLF)



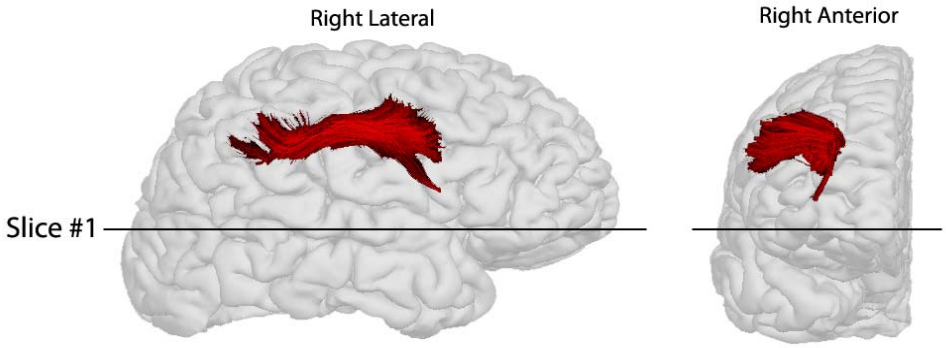


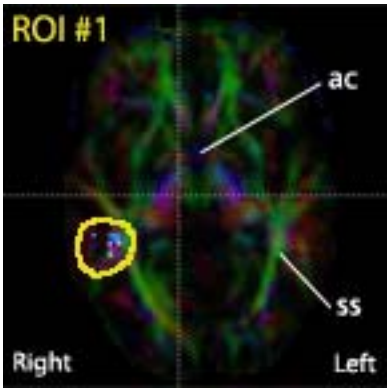
1. **ROI #1:** Load the final fiber bundle for the superior longitudinal fasciculus (slf). Identify the anterior commissure (ac) in an axial slice, defined by a red intensity spanning the interhemispheric fissure; this axial slice is chosen at Slice #1. Draw an 'AND' ROI around the visualized fibers on the axial slice, just lateral to the sagittal striatum (ss). *This is the same ROI as ROI #1 of the parietal part of the superior longitudinal fasciculus (pslf), except with an 'AND' operation.*
2. **'NOT' ROIs:**
    a. Remove remaining fibers extending superiorly to the parietal lobe.
    b. Remove fibers extending through the cingulum (cgh).

Final Fiber Bundle:



Superior longitudinal fasciculus, parietal part (pSLF)





1. **ROI #1:** Load the final fiber bundle for the main superior longitudinal fasciculus (slf). Identify the anterior commissure (ac) in an axial slice; this axial slice is chosen at Slice #1. Draw an 'NOT' ROI around the visualized fibers on the axial slice, just lateral to the sagittal striatum (ss). *This is the same ROI as ROI #1 of the temporal part of the superior longitudinal fasciculus (tslf), except with a 'NOT' operation.*
2. **'NOT' ROIs:**
    a. Remove remaining fibers extending inferiorly to the temporal lobe.

Final Fiber Bundle: