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CMA Methodology Overview

The CMA methods of analysis comprise general segmentation, cortical parcellation, subcortical parcellation, and white matter parcellation. These methods of analysis subserve *volumetrics* and *human brain mapping*.

Volumetrics

Volumetrics is a science dealing with brain structure measurements as well as algebraic relations that relate these volumes (Caviness, 1999). Because of their comprehensive and quantitative nature, our methods of analysis provide a set of volumes that can be used for statistical analysis of covariance and modeling (Cereb. Cortex, Kennedy, 1998), thus enabling characterization of normative data as well as comparisons with disease data sets.

Human brain mapping

The principle aim of our system provides a basis for brain function and metabolic activity mapping by determining a finite and specific set of quantifiable regions of interest or parcellation units.

The methods of general segmentation, cortical and subcortical parcellation, and white matter parcellation are designed in the context of a *neural systems approach* (namely, the motor system, perceptual (somatosensory, visual, auditory, gustatory, olfactory) systems, nociceptive (pain) system, cognitive (attention, executive, memory, visual/spatial, language) systems, and the affective (limbic) system). These methods may help elucidate basic questions in neuroscience, such as the relationships between cytoarchitectonic fields, cerebral connections, and neural functions.

A Guided Tour of CardViews

CardViews, short for cardinal views, is a program that creates visual images of the brain in the coronal, axial, and sagittal planes and displays them all on the same screen. This makes it easy to cross-reference a point you are not sure about. CardViews is used for segmentation and parcellation of the brain.

Type the following line at the prompt of any workstation in the "Cave":

cardviews 1110 2

The computer will "think" for a moment and then begin to load brain images corresponding to the second scan of subject 1110 in the lab's image database. The program that you are loading is called CardViews. The images that you see are actual magnetic resonance images from a real person. Aligned on the right side of the screen are the CARDinal VIEWS used in general anatomical study: coronal, as if the person is facing you; sagittal, as if you are staring right into their right ear; and axial, looking from the spine toward the top of the head (axial seems like a top-down view, but it's really bottom-up).

The left side of the images in any cardinal view is the right side of the brain.

The way the images were obtained allows CardViews to illustrate any area of the image in the three cardinal planes. Through the use of projection lines, any area can be cross-referenced to help determine sulcal boundaries, extent of gray matter areas, vasculature, nerves, etc. To see a quick illustration of this, single-click with the left mouse button on the rectangles called "auto trans" and "Projection." This will bring up crosshair lines. Now move the pointer to the large central image and double-click the left mouse button on any area of the image. You will see the other views change to show the intersection of the crosshairs in the other two planes. Experiment by double-clicking around the central image and watch the other views transform their images. The horizontal line in the central image shows the axial plane. The vertical line shows the sagittal plane.

There are slice numbers in the corner of each view. If you look above the central image you will see the same numbers next to the abbreviations "COR", "SAG", and "AXI." As you double-click around the central coronal image, you'll see the sagittal and axial numbers change to reflect the position of the projection lines.

In general, you will work with brains that have 64 or 128 coronal slices with 256 slices in the sagittal and coronal planes. The slice numbers referenced by the projection lines are listed next to COR, SAG, and AXI. The arrow buttons next to the numbers are another way to change slices. A single-click on any of the smaller images will bring it to the central window.

Single-click with the left mouse button on the word "Quit" at the top left of the CardViews window. This is how you quit the program. Start it up again like you did at the beginning (type "cardviews 1110 2"). Notice that Cardviews starts with the middle slice of the coronal plane (in this case slice 32 of a 64 slice brain) and that the slice 128 in both of the other two planes.

You can adjust the brightness and contrast of the screen to enable easier viewing. You will adjust the screen to many different levels of brightness and contrast depending on which structures you are

segmenting. To change the brightness and contrast, click in the central image box with the middle mouse button. Now move the mouse around. You should see the brightness of the image changing. Click the middle mouse button again while in the image box. This will set the image brightness and contrast. Play around with this feature for a bit. Notice that if you click in the lower right hand corner of the image box, and slide the mouse upwards, you will increase the brightness of the screen. If you then slide the mouse to your left, you will decrease the contrast of the screen. Watch how the outside of the brain seems to be larger or smaller depending on the brightness of the screen. Also note how the gray and white matter appear to "bleed" together as the contrast is decreased. After you're done, set the brightness/contrast to a level where you can see the edge of the brain without the white and gray bleeding together. Your cursor will be approximately two-thirds up in the image box, underneath the word AXI.

The exact position of your cursor will vary depending on which computer you are sitting at, so if your cursor isn't here, that's okay!

The Three Cardinal Views
Cardviews will display a sulcal line in all three planes. Make sure the "auto trans" button is on by single clicking on it (auto trans allows you to scroll through the three views with the up and down arrows next to the COR, SAG, and AXI slice numbers). If it is active, there will be a thick white line around the box. Move the mouse to the central image and single-click the right mouse button. You will see the words "NAV draw_mode" and something in green just above the central image. Draw a giant "X" across the coronal image: single-click the left mouse button at the top-left of the image and again at the bottom-right; single-click the right mouse button to exit from draw mode; initiate draw mode again by single-clicking the right mouse button; similar to before, left-click once at the top-right corner of the image and once at the bottom-left; then right-click to exit draw mode. If all went well, you should now have a green-colored " X" across the coronal slice.

Click on the sagittal image on the right side of the screen. This will bring the sagittal image to the central image screen. Now click in the up arrow next to the word SAG. You will notice some green dots move. As you continue to press the up arrow, you should notice the dots moving further apart. This is because you are moving laterally to the edge of the brain, and the dots are getting further apart as you approach the side of your "X." Click in the down arrow key to move medially. Eventually you will pass the center of the brain, and move laterally towards the right side of the brain. The dots will start to move further apart as you approach the other end of the "X."

Next click on the axial view to move this view to the center of your screen. Hit the up arrow next to the number by the word "AXI." You will again see the green dots come closer and further apart. These correspond to your "X." This demonstration was to help you understand how the different views are connected to one another, and how sulci lines appear in different views.

When you're done playing, quit cardviews. Then restart the program as you did before. When the NAV screen appears, turn on "auto trans." You are ready for the next section of the tour.

CardViews Four Modes
There are four modes in CardViews: NAVigation, SEGmentation, REView, and Tile Display. The buttons to change modes are just below "Quit." NAV mode is used to draw sulcal lines (for parcellation) and boundary lines that help to determine where one structure ends and another begins. SEG mode is used for segmenting structures and editing outlines. REV mode is used to

label the outlines and check for errors. Tile Display presents you with a larger series of brain slices which allows you to easily follow a structure through multiple slices. It can also be used to draw sulci lines, check for labeling errors, and compare the outlines from different segmentors.

NAV mode

So far you've been playing around in NAV mode. NAV mode is used for parcellation and to assist in segmentation. You will draw and save lines called sulci lines in this mode. Notice the word OVERLAY at the bottom of the screen, under the central image. Next to it is written the path where your sulci files are stored. You don't need to know what this means (that's what computer techs are for) but you should see 1110_2 written somewhere in this line. That indicates that you are working on brain 1110 scan 2. Below this line is the word "Prefix." You will save your sulci lines with your own personal prefix. To do this, first click on the line next to the word "Prefix." Enter your 3 initials, followed by the letter s. For example, if your name is John Frank Brown, you would enter jfbs. Then hit return. When you hit return, you should see the Sulci File line change. Your prefix now appears next to 1110_2. You are now ready to draw sulci lines.

To draw a sulci line, you will follow the same procedure you did previously to draw the "X." First enter draw mode by clicking the third mouse button. Then click where you want the line segment to begin with the first mouse button. Click at another point to draw a segment. Click somewhere else. You should have a line with 2 segments. Continue to play with the drawing feature. After you've finished drawing your line, make sure you hit the third button to exit draw mode and return to base mode. You can re-enter draw mode to reinitiate drawing in a different area.

To get rid of a line you don't like, click on it while you are in base mode. This will turn the line black. Continue to hold your cursor down on the now black line, and drag your cursor outside of the center image box. This will erase that sulci line.

To save your sulci lines, hit the "SAVE sulci" button at the bottom of the screen. Make sure you are in base mode when you hit the "SAVE sulci" button, or your sulci lines will not save. If you want to save more lines, hit "SAVE sulci" again after drawing them. A window will pop up asking if you want to overwrite your existing file. Click on the "Overwrite" button to save your new sulci.

SEG mode

SEG mode is used to segment. To enter SEG mode, click on the "SEG" button under "Quit." If you look at the top box under the three boxes for NAV, SEG, and REV mode, you will see the word SEG on the second line. Next to it is the word base, indicating that you are in base mode. There are many different drawing methods available for use in SEG mode. The method you are using will always appear next to the word SEG.

Underneath the center image block you should see a line that reads OVERLAY. This is similar to the SULCI FILE in NAV mode in that it tells you what brain you are working on. Below that is the prefix line. In SEG mode, your prefix is just your initials (no "s."). For example, if your name is John Frank Brown, your prefix is jfb. Click on the line next to the word "prefix." Enter your initials, and hit return. You should see your initials become part of the line next to OVERLAY.

There are a few differences between NAV mode and SEG mode. One of the most apparent differences is the way projection lines work. Up to this point you've been playing with the projection lines in NAV mode. In SEG mode, they are not as automatic. Click on the projection box to bring up the crosshairs. In NAV mode, you could double click anywhere on the image in the center box to

reveal the same place in the sag and axial views. This doesn't work in SEG mode. To move the crosshairs to a specific point, use scroll bars next to the small coronal image in the right side of the screen. Using the knobs on these scroll bars, position the crosshairs to the area you want to investigate. Then hit the "Transform" button next to the SAG and AXI words. This will move the crosshairs to that position in these 2 views. Click the "Projection" button to turn off the projection lines.

The point of SEG mode is to create outlines (also referred to as "otls") that can be used in volumetric analysis. For example, you will create an outline of the amygdala on every slice that has amygdala. This enables statisticians to estimate the amygdala volume for the brain. There are four drawing methods we use to help in creating outlines: the intensity contour, the histogram, drawing, and the optional auto-seg. These are all explained in greater detail in the "General Methods and Tools of Segmentation" section. Anytime you enter into one of these drawing methods, the word "ok" in the upper left box will change, to indicate which method you are in. When you exit that method, that word will return to "base."

The four methods of drawing enable you to trace brain structures. When you are done tracing a particular structure, you extract it. Extracted outlines can be saved, labeled, and are what we use in analysis.

Now we'll try and create a simple outline. We'll do this by drawing. Drawing in seg mode works slightly differently than it does in NAV mode. Place your cursor in the center image box. Click the right mouse button. You'll notice you've switched from "base" to "draw_mode." Hold down the first mouse button and drag it across the screen. You've just drawn a line. Now click the right mouse button again to exit draw mode. Now try to draw a circle. Click the right mouse button again to enter draw mode. Hold down the left mouse button and draw a closed circle; this can be a sloppy circle, just make sure you create some sort of closed shape. Click the right mouse button again to exit draw mode. Now place your cursor inside the circle. Press "e" to extract the outline. You'll notice part of
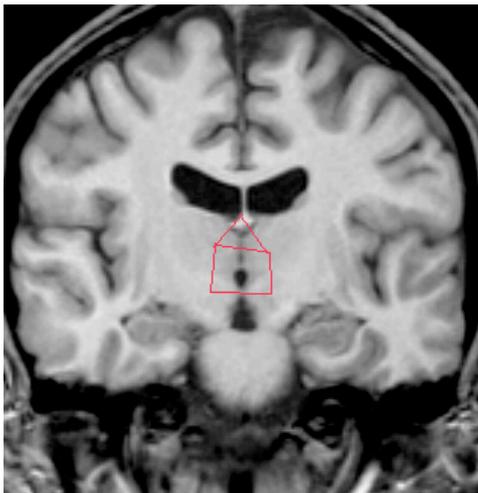
your red circle is now green. Hit the "SAVE" button. Now hit the clear button. How hit the load button. If all went well, your green outline was saved, and loaded, and the red contour disappeared when you hit the clear button; this is because only extracted outlines can be saved.

Notice that there are eight colored boxes in the upper left white box. We'll focus on the first five. These boxes are your contour boxes. There is a small black box in the red box. This means that any contours you create or erase will be red. Using the method described above, draw a red line (make sure to exit draw mode when you are done). Now click on the yellow box. The little black box has moved from the red box to the yellow box. Draw a line. It should be yellow. Now hit "x." The "x" function is used to get rid of all contours of a given color. Your yellow line should be gone, but the red one still remains. Click on the red box. Now hit "x." The red contour should be gone. Play around with the 5 different colored contours. Draw different shapes in different colors, and extract them. You'll notice that no matter what color you draw a shape in, it will always turn green when you extract it. You can even create shapes out of two different colored contours. Being able to create outlines using many different colored contours makes segmenting easier and faster.

The concept of extracting is a bit tricky to understand. Here is an exercise to try to make it clearer. First hit the clear button to clear the screen. Next draw a house: First draw a square (make sure that there are no gaps between the four sides). Now draw a triangle roof on top of the square; making sure the ends of the roof touch the top of the box, and that the two slanted sides of the roof intersect.

Place your cursor inside the triangle (roof) and press "e" to extract it. Only the triangle should turn green. Now hit "w," this un-extracts the last thing you extracted (in this case the triangle). Place your cursor inside the box and extract it. Only the box is green. Hit "w" to unextract it. Now place your cursor underneath the box. Hit x. You'll notice that your "house" is green: the shape comprised of 3 sides of the box and 2 sides of the triangle was extracted.

The way the extract command works is as follows: The program detects the first contour you drew that is immediately ABOVE your mouse cursor. Then it follows that contour all the way around until the contour ends. So if you are INSIDE an enclosed shape like your box, the program detects the upper part of the box, and then follows the contour all the way around along the inside of the box. When you extract the house from the OUTSIDE, the cursor hits the bottom of the box, and then follows around the outside of the house. In order to create outlines that can be used in analysis, all structures must be extracted from the inside. We often extract things from the outside as a useful tool during segmentation (this will be described in the methods section). However, remember that structures must be extracted from the inside in order to be used in morphometric analysis.

While you are segmenting, the easiest way to move around is to use the "-" and "+" buttons underneath your prefix. This will automatically change your saved outlines as you change slices.

After you have extracted structures on a slice, you must click the "Save" button before moving to the next slice using the "+" and "-" buttons. Otherwise, you will lose your outlines.

REV mode
Click on the REV button. You'll notice the "review panel" pop up in the left corner of the screen. Review mode is used to check and label the brain. There isn't much to play with until you actually have some saved "otls."

Tile Display Mode
Click on the tile display button. A large screen will appear. Click on the "GO" button that is about one quarter down from the top of the screen. You should see a whole bunch of brain images. Tile display enables you to see many slices at one time and is used to check the brain, examine tricky areas, and draw sulci lines. Notice the numbers and scroll bars at the top of the screen. These indicate which slices you are on, and allow you to move to different slices. Just a warning... these scroll bars are tricky to use. Click on the TOP scroll bar and drag it all the way to your left. As you did that, the bottom scroll bar also moved left. You should see the number 3 on the top line, and 32 on the bottom line. Click the "GO" button again. You are now looking at slices 3-32. Click on the BOTTOM scroll bar and drag it to your right. When you do this, make sure you do not drag the mouse cursor outside of that left panel (that is, not past the white line that separates the buttons from the brain images). The program will not cooperate with you if you drag your cursor too far. The top line should read 30, and the bottom should read 59. Click GO again. You are looking at slices 30-59.

Click on the box next to the word "zoom" that is located to the left of the GO button. You'll notice the slice numbers next to the scroll bar have changed. Now click on GO. You are looking at six zoomed

images. Play around with the scroll bars to move to different slices. Always click GO to transform the images. If you want to look at the smaller images again, just click the box next to zoom to turn off this feature. And then click GO.

You can look at multiple sagittal or axial images by clicking the sag or axi box underneath the scroll bars. Then click on GO.

As with review mode, there isn't a lot more you can do in tile display without segmenting first.

To return to the main page of CardViews, click on the CARDVWS button.

Cortical Parcellation – Getting Started

Cortical parcellation is our MRI-based methodology used to subdivide the human cortex into discrete, volumetrically identifiable "closed" regions of interest. This method is applied on any particular brain under investigation and utilizes topographical descriptors, i.e. fissures and nodes/planes of the individual brain.

Naming Your Files

Parcellation requires the assignment of fissures, nodes, and parcellation units. Upon opening CardViews, the first step is to give a name to these new files. When you enter CardViews you will be in NAV mode. The general format for entering the information on how to name your files is:

":ce 'your segmentation prefix' 'your sulci prefix' 'your parcellation prefix'"

Note where there are spaces in this format. Now click on the central image in NAV mode and type:

":ce"

This will tell CardViews that you are about to enter the prefixes it will use to name the various files you will create while drawing sulci, defining nodes, and defining parcellation units. Next, type:

"your segmentation prefix" (usually your initials followed by an "I"
      (upper-case "i" not to be confused with a lower-case "L")
"your sulci prefix" (your segmentation prefix followed by an "s" without any spaces)
"your parcellation prefix" (your sulci prefix followed by a "J" without any spaces)

For example, if your name was Amy Leigh Sonricker you would type:

:ce alsI alss alssJ

By setting these parameters the program knows how to overlay the sulci and nodes onto the segmentation, and what to call the resultant outline file.

What the Prefixes Mean

Segmentation files are generally saved with your initials as the file name, followed by an "I" which tells CardViews to load the "I-files" which have a cortical ribbon for you to parcellate. Sulci files are saved with an "s" at the end of your initials as the file name. The "s" stands for sulci. Parcellation files are saved with both the "s" as well as a capital "J" at the end of your initials as the file name. The "J" stands for Jim Meyer, the original programmer of CardViews (he wanted to go down in history as a part of CardViews, thanks Jim!).

Left and Right

It is also important to be sure that you understand where the "left" and "right" side of the brain are located in the different views. In coronal views, "left" and "right" are as if you were looking at a persons face; therefore "your right" is the coronal sections "left." In sagittal views the lower numbered sections are the right side, whereas the higher numbered sections are the left side. In axial views, you are looking from underneath upon the section; therefore "your right" is the axial sections "left."

Sulci

The first objective of parcellation is to identify the limiting sulci. This is best accomplished in the tile display environment of cardviews.

Using Tile Display
Tile display allows you to easily follow the course of a sulcus over several adjacent slices of brain, which makes identification and tracing of sulci much easier. Although sulci can be drawn and saved in the NAV mode of cardviews, it is usually much easier to draw and save them in tile display. To get into this environment, click with the left button on the "tile display" icon above the cardviews information box (from here forward, "click" refers to press the left mouse button unless otherwise noted).

Once in tile display, a good strategy is to load and save all the views you will need to identify the limiting sulci. This includes coronals, dorsal and ventral axials, and medial and lateral sagittals for each hemisphere.

Creating Views in Tile Display
In the upper left corner of the window, in the menu column, the range and type of images to be displayed are shown. Click in the box adjacent to the view you wish to display (a check will mark that box). The range of slices to be displayed is shown on the bars above these boxes. The range can be changed by clicking on either of the bar icons and by dragging the icon to the left or right. Clicking on the arrowheads next to the view labels (cor, sag, axi) is another way to change the range. When you have selected the desired range, hit the "GO" icon. This will display the slices you selected.

Saving Views in Tile Display
To save views of these slices, click on one of the "SAVE" icons which can be found in the middle of the menu column. The type and range of the saved slices will appear on the left of the "SAVE" icon and the "RCL" (recall) icon to the right will brighten. By clicking on the upward arrowhead above the "SAVE" icons, more slots will appear. Display and save the six views you will need to identify the sulci necessary for parcellation. To view a previously saved display, hit the "RCL" icon adjacent to the slot where that display was saved.

In order to have your sulci lines continue to appear in TileDisplay you must save the view each time you draw a sulci (this does not save your sulci to a file, just temporarily saves the view you are looking at). If you find your sulci lines disappearing, click the box next to"SULCI" to display them. Do not redraw.

When you have saved these six views, you are ready to identify and draw the limiting sulci.

Dorsal Axial View

The dorsal axial views are a convenient place to start, but one could start from any view of the brain. Here is described one way of tracing the limiting sulci in which we start from the central sulcus. The dorsal axial views allow the visualization of the precentral, central, and postcentral sulci, as well as the superior frontal sulcus and the intraparietal sulcus, and sometimes the intermediate sulcus of Jensen (Jensen's is best left to be done later using a lateral sagittal view where it is easily identified). Dorsal axial views are a good starting place because the central, precentral, and postcentral sulci can usually be easily discerned from the high axial view. Sulci should be drawn in the "zoomed" view, for clarity.

Zooming In

To zoom your view, click in the area of the brain where the sulcus you want to draw is found. Click on the "SET" icon near the top of the menu column, and then click on one of the boxes adjacent to the "cor," "sag," or "axi" icons near the top of the menu column. Click on the box adjacent to the "ZOOM" icon, and click on the "GO" icon. This will display a series of slices that centers on the coordinate you clicked on earlier. This is a convenient method for closely following the course of a specific sulcus, and also allows you to see the slices clearly.

It is often necessary to cross-reference views in order to understand where the sulci should be drawn.

Returning to CardViews Display

You can return to the CardViews display to utilize the cross-reference projection lines. In TileDisplay, click on the slice you wish to study, then click on the "cor", "sag", or "axi", box in the middle of the menu bar, whichever you wish to see. The cardviews display will appear with the selected slice in the view box.

Precentral, Central and Postcentral Sulci
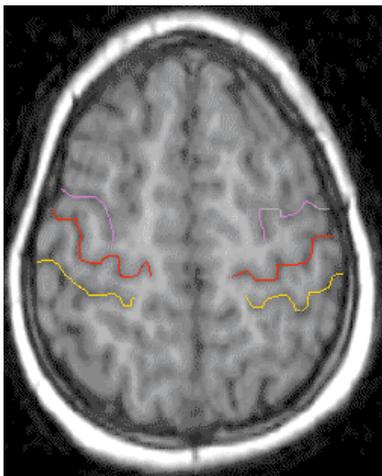
The central sulcus divides the frontal and parietal lobes. It starts at the vertex of the brain where it is usually visible on the medial surface and courses anteroventrally to a point near the superior lip of the Sylvian fissure. It is sometimes separated from the Sylvian fissure by the subcentral gyrus, and may be divided into superior and inferior segments. On either side of the axial slice, find the central sulcus, which is the middle one of the three sulci. This sulcus is normally highly regular and continuous, so it is a nice orientation landmark.

If any of these sulci bifurcate, the posterior branch should be drawn.

Drawing Sulci

To draw the sulcus click on the right mouse button; this activates the drawing mode. Click the left button with the cursor on the point where you wish to begin drawing. Click again at some other point along the sulcus. A sulcus line will appear, connecting the two points. All sulci lines are drawn in this fashion. A previously drawn line can be erased by clicking on the middle mouse button, provided you have not left the drawing mode (by clicking on the right button). Once you have left the drawing mode simply left-click on the drawn sulci, drag it out of the area, and release the left mouse button to remove the drawn sulci.

Be sure to exit draw mode each time you finish drawing a sulcus*.*

Choosing a Pen Color

To aid in parcellation, the sulci are drawn color-coded. To access the central sulcus "pen" (or any other sulcus "pen"), hit the letter "s." A sulci menu appears. Click on the desired sulcus and hit the space bar to exit the sulci menu.

Because it is necessary to draw on cross sections of the brain, sulci must be drawn on several different slices to capture the complete extent of that sulcus. The central sulcus falls into this category. Draw the central sulcus on a slice that contains much of its lateral extent. Then follow the sulcus in progressively higher (more dorsal) slices until it finally reaches the hemispheric margin (or its most medial extent if it does not reach the hemispheric margin).

Using the Cross-Hair Tool

A cross-hair tool is available to make this task easier. Click on the "create" icon that is located toward the bottom of the menu column. A green cross will appear in each of the slices displayed. Click on a point where the central sulcus can clearly be found. The cross will then move to this point. It will also appear at corresponding points on the other slices. (Keep in mind that it corresponds to a coordinate in the field that contains the slice and not to the anatomical marker).

Draw the sulcus on enough slices to cover its full medial-lateral extent.

Saving Sulci

To save these sulci lines, click on the "WRITE SULCI" icon in the lower left corner of the menu column. You will sometimes have to click "OVERWRITE" to complete the save (this happens if you have previously saved sulci during the current CardViews session). This saves your sulci to a permanent file. Each time you save, it overwrites the previous save.

Do the same for the precentral and post central sulci. Remember to use the correct pen. These sulci are often not continuous so care must be taken to identify the different segments of each sulci. The precentral sulcus divides the precentral gyrus from the three frontal gyri. It follows a dorsomedial to ventrolateral path that is rostral and roughly parallel to the course to the central sulcus. Variably it continues onto the medial surface of the brain. The precentral sulcus is usually divided into superior and inferior segments. The postcentral sulcus lies posterior to the central sulcus and roughly parallels the central sulcus from the dorsal hemispheric margin to the Sylvian fissure. The postcentral sulcus is frequently discontinuous.

These sulci often do not reach the hemispheric margin. If they do not, follow them as far medially as possible. As a general rule, more dorsal = more medial, but this is not the case for every brain. For speed and better accuracy, it is recommended that you completely draw a particular sulcus in each hemisphere first, then move to another sulcus.

Superior Frontal Sulcus
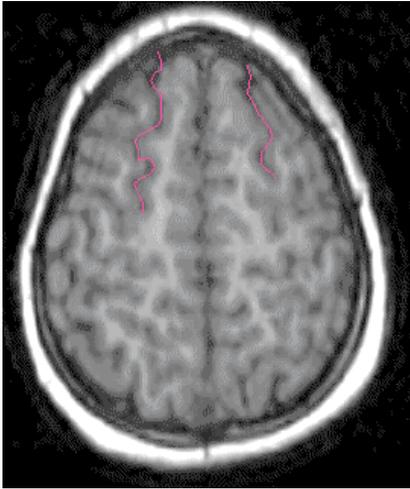
Now draw the superior frontal sulcus. It begins at the dorsomedial rostral tip of the brain and continues caudally until it hits the precentral. The superior frontal sulcus follows a course parallel to the interhemispheric plane throughout the frontal lobe and extends posteriorly to the precentral sulcus, which it meets at a right angle. It is best viewed on axial slices of the brain.

Intraparietal Sulcus
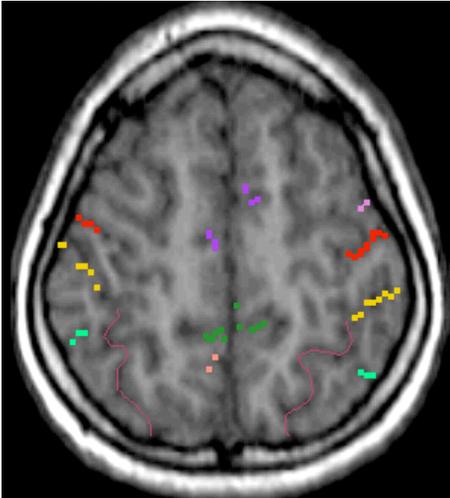
Finally, draw the intraparietal sulcus. This sulcus also courses rostro-caudally. It begins dorsomedially at the postcentral sulcus and continues, often in a circuitous fashion, toward the caudal tip of the brain. It follows a roughly transaxial course which partitions the superior and inferior parietal lobules. Rostrally it meets the postcentral sulcus.

Medial Sagittal View

Recall the medial sagittal slices. The medial sagittal sulci include the cingulate sulcus, paracingulate sulcus, subparietal sulcus, calcarine sulcus, pariteoccipital sulcus, and the cuneal sulcus.

Cingulate Sulcus
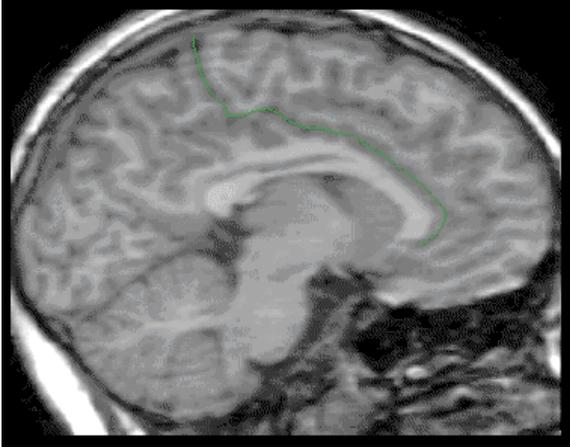
The cingulate sulcus follows a course parallel to the corpus callosum. Posteriorly, it courses dorsally and terminates near the hemispheric margin caudal to the central sulcus. It is considered as the first major sulcus above the corpus callosum. Trace the full course of the cingulate sulcus.

Check and verify in coronals; the cingulate is the first sulcus you will see above the corpus callosum*.*

Paracingulate Sulcus
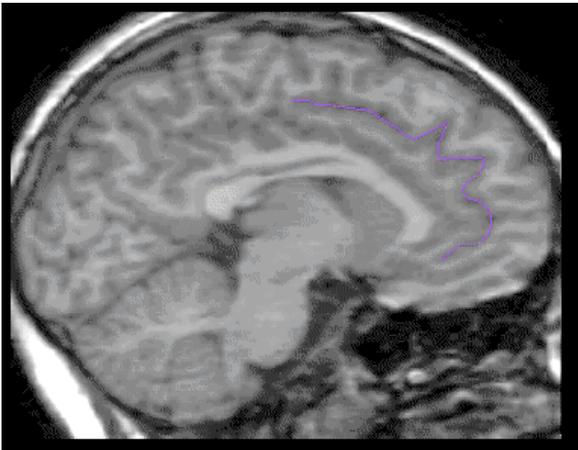
The paracingulate sulcus lies just in front of and parallel to the cingulate gyrus. It is often discontinuous. It runs roughly parallel to the cingulate but does not continue as far posteriorly.

Subparietal sulcus
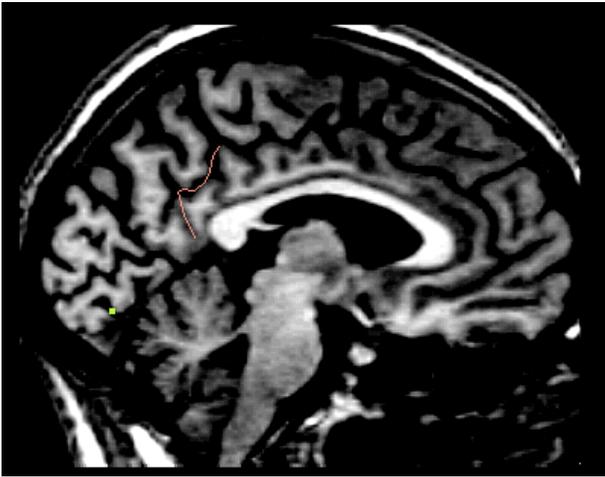
The subparietal sulcus lies behind the corpus callosum, hitting the cingulate dorsally. It often has an "H" shape as seen in this example. Trace it as far ventrally as possible following the example shown here; it should connect to the cingulate sulcus superiorly, and extend to the calcarine sulcus inferiorly.

Calcarine Sulcus
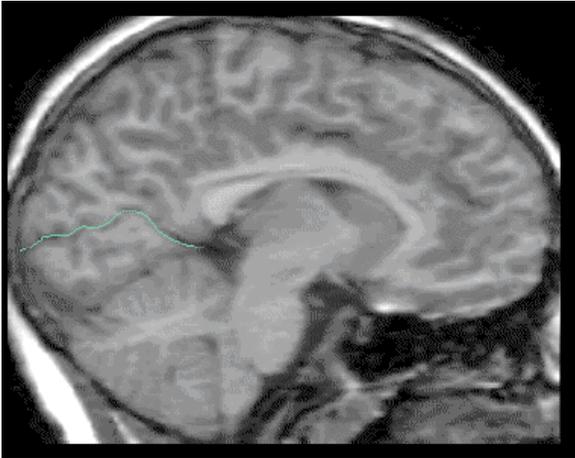
The calcarine sulcus extends from near the occipital pole to a point just below the splenium of the corpus callosum. Draw the calcarine sulcus medially to get its posterior end, and laterally to get its anterior end.

Parietooccipital Sulcus
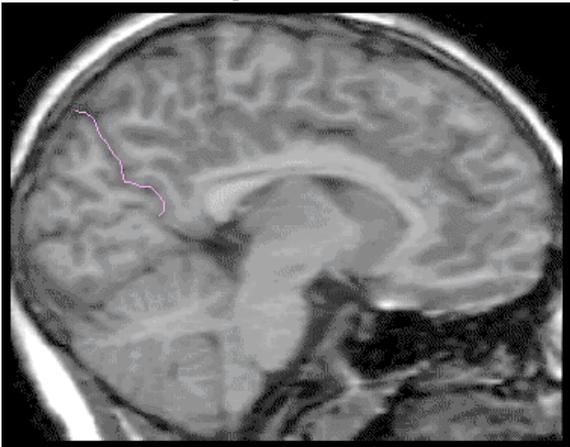
The arietoccipital sulcus follows a typical course from a dorso-caudal point at the hemispheric margin, to an anteroventral point at the junction with the calcarine sulcus. Draw the Parietooccipital sulcus to capture its full extent.

The Parietooccipital sulcus may branch near the hemispheric margin; if it does take the most anterior branch.

Cuneal Sulcus
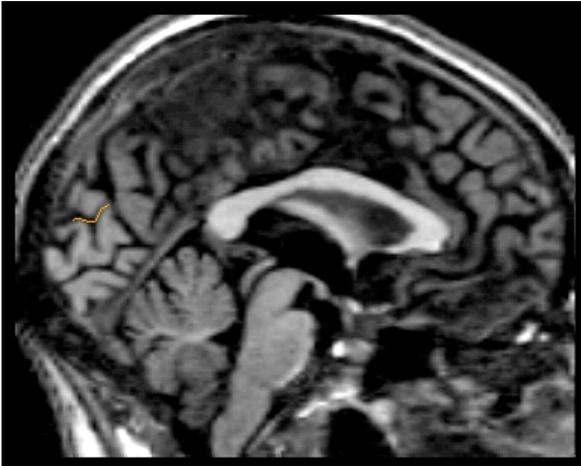
Now draw the elusive cuneal sulcus. It is often necessary to refer to the coronal view to find this sulcus. Locate the calcarine sulcus on the coronal and follow caudally until it separates from the Parietooccipital sulcus (the cuneal point). Continue caudally and look for a small sulcus to emerge between the calcarine and parietooccipital sulci. This is the cuneal sulcus

If more than one sulcus emerges between the calcarine and the parietooccipital, the cuneal is the one closest to the calcarine.

Return to the sagittal view and trace the cuneal.

Lateral Sagittal View

Recall a saved lateral sagittal view. The lateral sagittal sulci include the circular sulcus of the insula, precentral, central and postcentral sulci, inferior frontal sulci, posterior horizontal and posterior ascending rami of the Sylvian fissure, anterior horizontal and anterior ascending rami of the Sylvian fissure, superior and inferior temporal sulci, the angular sulcus, the lateral occipital sulcus, and the intermediate sulcus of Jensen. The dorsal axial sulci that were done previously will serve as guides for some of these sulci.

Circular Sulcus of the Insula
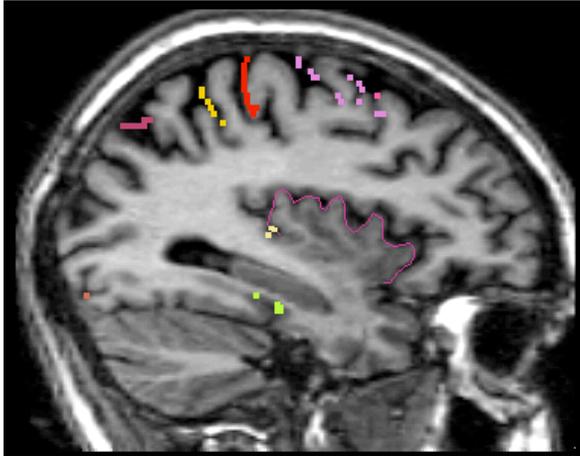
Locate the insular cortex on a sagittal section. The circular sulcus of the insula is the entire series of sulci surrounding the insula and forming a "fan shape." The entire sulcus will not be visible in every sagittal section. Trace this sulcus from its appearance to its disappearance in successive sagittal sections to its dorsal/ventral and rostral/caudal extremes.

Viewing Previously Drawn Sulci

With the lateral sagittal view displayed, click on the arrowhead next to the "SULCI" icon in the upper half of the menu column. This superimposes the drawn sulci lines on the display. The traversing axial sulci will appear as dots on the sagittal plane.

Precentral, Central, and Postcentral Sulci
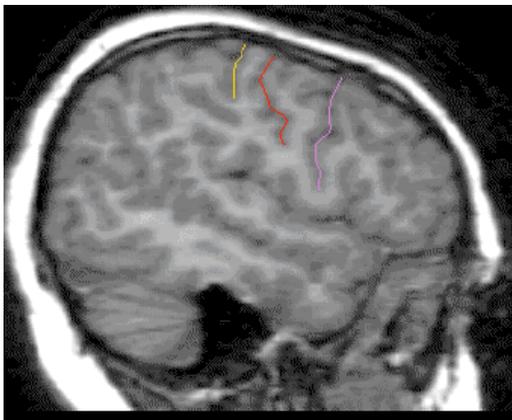
The central sulcus divides the frontal and parietal lobes. It starts at the vertex of the brain where it is usually visible on the medial surface and courses anteroventrally to a point near the superior lip of the Sylvian fissure. It is sometimes separated from the Sylvian fissure by the subcentral gyrus and may be divided into superior and inferior segments. The precentral sulcus divides the precentral gyrus from the three frontal gyri. It follows a dorsomedial to ventrolateral path that is rostral and roughly parallel to the course to the central sulcus. Variably it continues onto the medial surface of the brain. The precentral sulcus is usually divided into superior and inferior segments. The postcentral sulcus lies posterior to the central sulcus and roughly parallels the central sulcus from the dorsal hemispheric margin to the Sylvian fissure. The postcentral sulcus is frequently discontinuous. Trace the central, postcentral, and precentral sulci from the hemispheric margin dorsally to the Sylvian fissure ventrally. Once again, this must be done on several slices to capture the full course of the sulci. The precentral sulcus is usually segmented with the more lateral segment lying further rostrally than the medial segment. It may also be closer to the Sylvian fissure in its lateral extents.

Inferior Frontal Sulcus
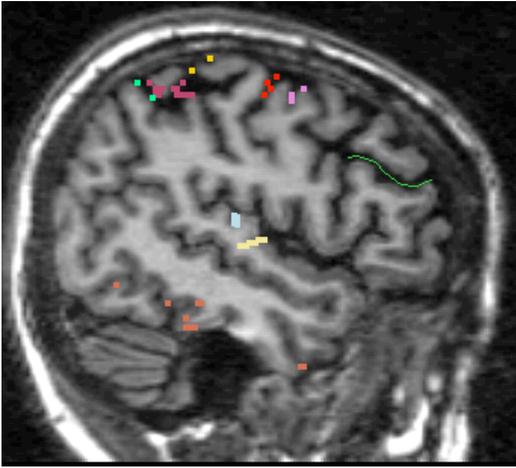
The inferior frontal sulcus lies ventral to, and parallels the superior frontal sulcus. Posteriorly, it also meets the precentral sulcus at a right angle.

Be careful not to draw the medial frontal sulcus.

Posterior Horizontal Ramus of the Sylvian Fissure & Posterior Ascending Ramus of the Sylvian Fissure
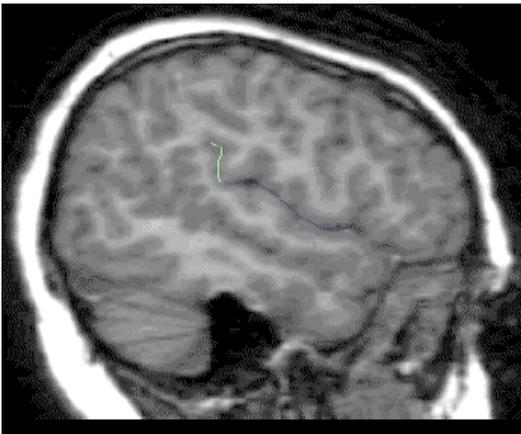

The horizontal ramus of the posterior Sylvian fissure is the dominant fissure of the lateral hemisphere. It is bordered inferiorly by the supratemporal plane and superiorly by the frontal and parietal opercula. The ascending ramus of the posterior Sylvian fissure represents the axis of the supramarginal gyrus. It is the main caudal extension of the posterior horizontal ramus of the Sylvian fissure. It angles dorsally as it courses caudally. The posterior Sylvian fissure is the most obvious fissure on the lateral sagittal plane, so draw the horizontal and ascending rami.

Anterior Horizontal Ramus of the Sylvian Fissure &
Anterior Ascending Ramus of the Sylvian Fissure
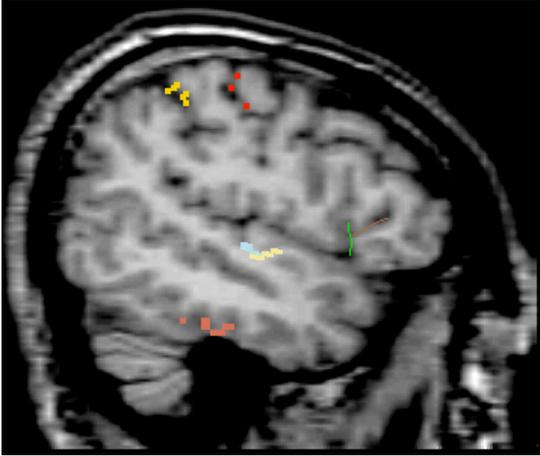
The horizontal ramus of the anterior Sylvian fissure is the most rostrally continuing segment of the Sylvian fissure. Caudally, it begins at a point immediately anterior to the inferior precentral sulcus. It then courses rostrally. The ascending ramus of the anterior Sylvian fissure also begins caudally at a point immediately anterior to the inferior precentral sulcus. From this point it courses dorsally and rostrally such that the aar and ahr form a "V" with the open end facing anteriorly. The anterior rami of the Sylvian lie rostral to the precentral. The ascending and horizontal normally form a "V" shape with the horizontal running parallel to the inferior frontal fissure. These should be drawn with care and often require reference to the coronal view.
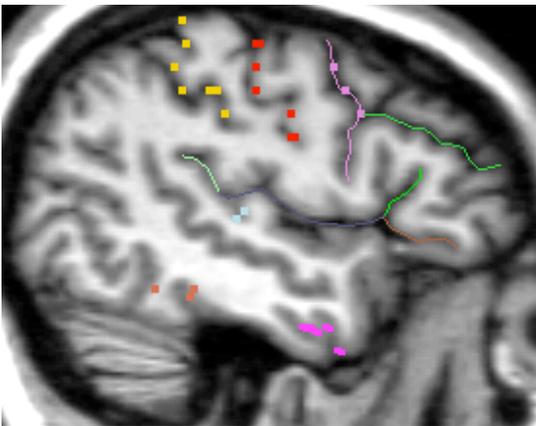
The diagonal sulcus (pictured here), found in 50% of brains, is located between the anterior ascending and precentral sulci; make sure you take the most anterior sulcus present for the anterior ascending sulcus.

Superior Temporal Sulcus
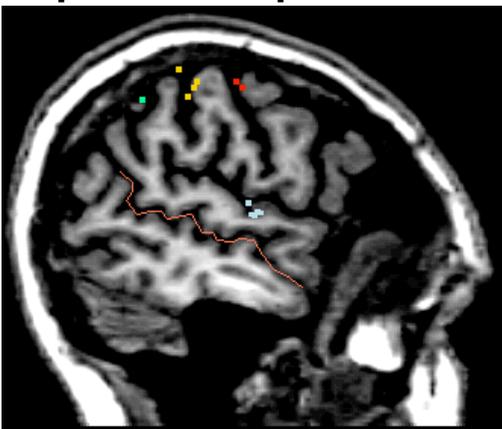
The superior temporal sulcus lies ventral to and parallel to the posterior horizontal ramus of the Sylvian fissure. Posteriorly it gives rise to the angular sulcus, and the lateral occipital sulcus.
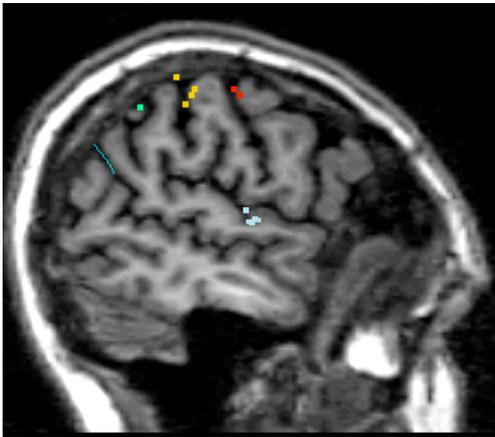
Angular Sulcus

The angular sulcus, anteriorly, is continuous with the superior temporal sulcus. Posteriorly it arches dorsally such that it is caudal and parallel to the posterior ascending ramus of the Sylvian fissure. At the caudal tip of the superior temporal sulcus, the angular sulcus begins and continues dorsally.

Lateral Occipital Sulcus
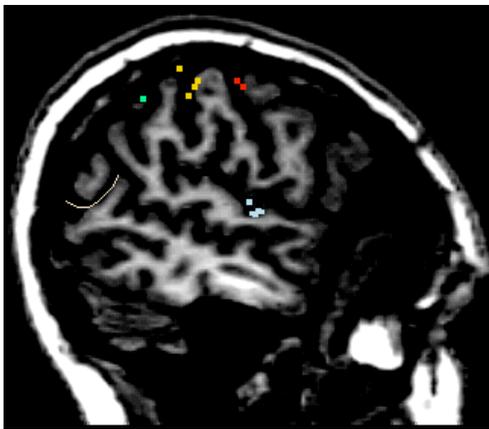
The lateral occipital sulcus should be drawn next. It also begins at the caudal tip of the superior temporal sulcus but continues further caudally and often slightly ventrally.

Check the coronal view if the lateral occipital is not easily apparent in the sagittal view; the lateral occipital is the deep sulcus that bisects each coronal slice at its equator.

Intermediate Sulcus of Jensen
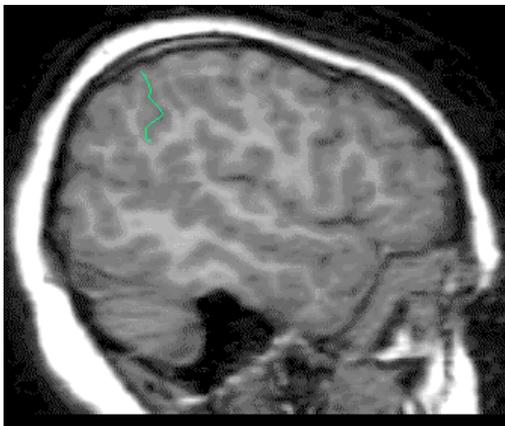
The intermediate sulcus of Jensen is a downward-projecting side branch of the intraparietal sulcus. It descends across the inferior parietal lobule. The Intermediate sulcus of Jensen begins at the dorsal hemispheric margin, and splits the area between the posterior ascending ramus of the Sylvian and the angular gyrus as it courses ventrally. Return to the dorsal axial slices. Locate the Intermediate sulcus of Jensen on both sides. Trace the sulcus from the lateral margin to its most medial extent, where it will usually intersect either the intraparietal sulcus or the postcentral sulcus.

Inferior Temporal Sulcus
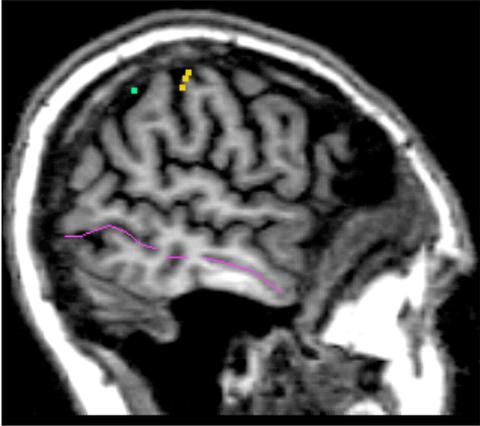
Returning to the lateral sagittal view, trace the segmented inferior temporal sulcus.

Ventral Axial View

Now recall the ventral axial slices. The ventral axial sulci include the olfactory sulcus, collateral sulcus, and the occipitotemporal sulcus.

Olfactory Sulcus
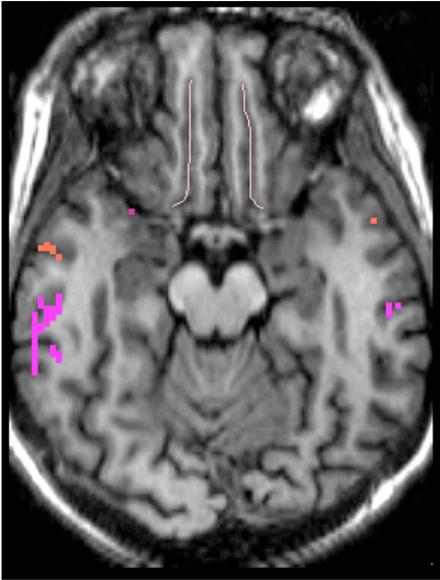
The olfactory sulcus lies just lateral to the medial hemispheric margin on the ventral surface of the brain follows a parasagittal course. At its posterior end, the olfactory sulcus splits, take the lateral portion. Draw the very regular olfactory sulci on both sides.

Collateral Sulcus
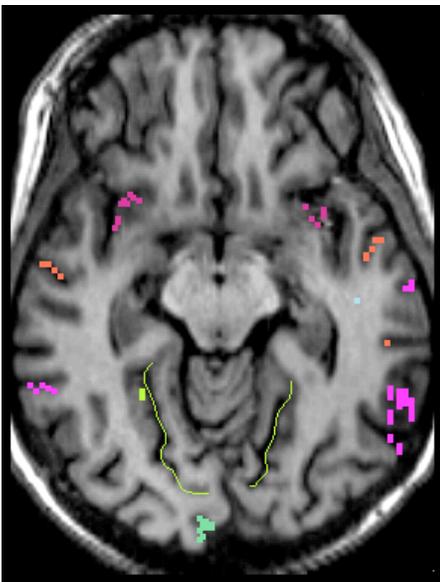
The collateral sulcus courses along the ventro-medial surface of the temporal and occipital lobes. It follows closely the parahippocampal gyrus anteriorly and the lingual gyrus posteriorly. Locate the collateral sulcus in one hemisphere. At a point along its course, the collateral will appear to run mediolaterally from the medial hemispheric margin. Return to cardviews and select a sagittal slice that bisects this segment of the collateral. You will see a portion of the collateral on this sagittal slice that runs below and roughly parallel to the hippocampus in the temporal lobe. Draw the collateral here. Do the same for the other hemisphere, then return to the axial dorsal axial slices in tile display. Display the collateral sulci you just drew (by clicking the "sulci" icon). Draw in the rest of the collateral on both hemispheres. Be sure to capture its full rostro-caudal extent. Posteriorly, it splits into two major segments. Trace the most medial of these segments.

Occipitotemporal Sulcus
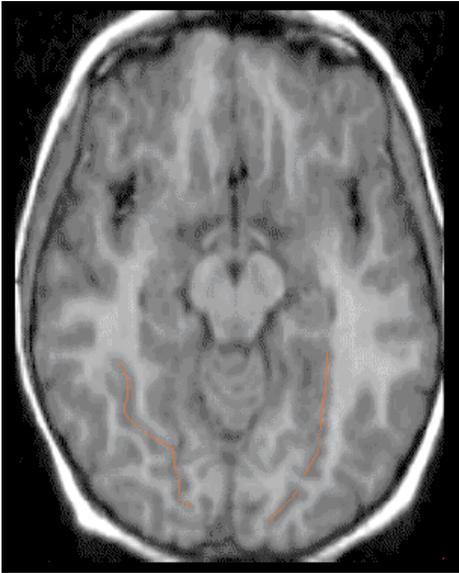
The occipitotemporal sulcus is located on the ventral surface of the temporal and occipital lobes. It follows an approximately parallel course to the ventrolateral hemispheric margin and the collateral sulcus; located between the ventrolateral hemispheric margin and collateral sulcus. Trace the occipitotemporal sulcus. This sulcus follows a path roughly parallel to that of the collateral sulcus. Posteriorly, it often courses toward the lateral hemispheric margin and then returns medially in the occipital region.

Coronal View

Now recall the coronal slices. The coronal sulci include Heschl's sulcus, and the first transverse sulcus.

Heschl's Sulcus
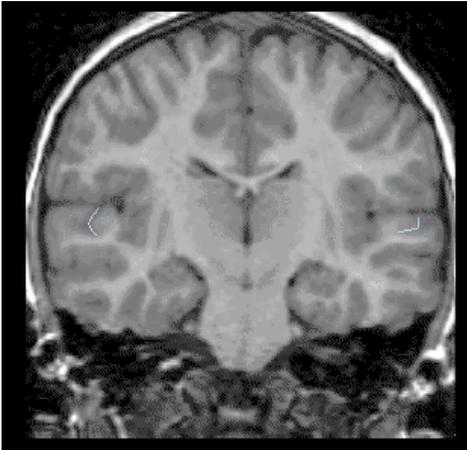
Heschl's sulcus is the diagonal sulcus immediately behind the Heschl gyrus. Watch for an evagination on the ventral side of the sylvian fissure to occur as you course through successive coronal sections. This evagination is Heschl's gyrus, and you will find Heschl's sulcus immediately lateral to the gyrus forming part of the "neck" of the evagination. Trace this sulcus from its appearance to its disappearance in successive coronal sections.

It is often the case that two, or possibly more, Heschl's gyri could occur. If this is the case, the most medial gyrus is H1, and the rest are named consecutively proceeding laterally. In this situation the most lateral sulcus (partially forming the "neck" of one of the evaginations) is Heschl's sulcus.

First Transverse Sulcus
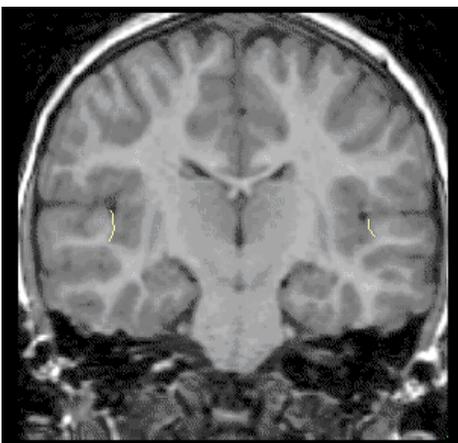
The first transverse sulcus lies just in front of and parallel to Heschl's gyrus which is the anterior most ransverse gyrus on the posterior supratemporal plane. On the medial side of Heschl's gyrus you will find the first transverse sulcus, forming the other part of the evaginations "neck." Trace this sulcus from its appearance to its disappearance in successive coronal sections.

In cases with multiple Heschl's gyri, the most medial sulcus (partially forming the "neck" of one of the evaginations) is the first transverse sulcus.

Nodes and Planes

Nodes and planes need to be identified after you have already traced all of your limiting fissures. The nodes and planes are points that serve as landmarks for specific positions along the X, Y, and Z-axes. Some of these landmarks are the intersection of two fissures, while others are indicated by the most caudal or most rostral point of a particular fissure or structure.

All of the planes and nodes that you need to identify can be divided into four basic categories of identification; the coronal series, axial series, mid-sagittal series, and lateral sagittal series. The section containing topographic descriptions of planes and nodes is divided into these different series for your convenience. In general, you need to identify each of the nodes and planes in both the right and left hemispheres.

The procedure for finding the nodes and planes is similar for each of the four different groups. To identify nodes and planes in the coronal series, first read the topographic description which gives hints on how to identify the appropriate caudal to rostral plane for a given node or plane.

In the tile view mode, view the screen of unzoomed coronals that you saved as one of your RCL files. From this view, identify the area in which you need to look to define a particular node or plane and click on one of the slices in that region. Zoom in to this slice, which will allow you to view the area of interest more closely. It is in this zoomed view that you will select a given node or plane. When you have identified where you want to click for a particular node or plane, save the zoomed view with one of your remaining RCL files.

Setting a Node/Plane
Click on the node or plane, then type "n" on the keyboard. When you type "n", the menu for nodes and planes will appear. Click on the zeros that appear next to the node that you are identifying and the location of that node will appear.

It may be helpful to create a "mark" where you click, to be sure you clicked on the right place. To do this, hit the "CREATE" button and then click on the slice where the node will be defined. this will create a green dot on this place you clicked. Clicking "DESTROY" will remove that green dot.

Deleting/Overwriting a Node/Plane
If you make a mistake, press the "u" key to "undo" the last node/plane you set, and return it to its previous state. You can also overwrite nodes/planes simply by clicking on the numbers next to the name of the node/plane.

Saving Nodes/Planes
Save nodes and planes by clicking on the box at the bottom left corner of the screen that says "NODES" and then on the "save" box that appears. When you are done saving you can click "cancel/done" to close the box.

Although all final judgments will be made in the coronal view for the following nodes and planes, you will usually need to use more than one of the cardinal views-coronal, sagittal, and axial-for identification purposes.

Left and Right

It is also important to be sure that you understand where the "left" and "right" side of the brain are located in the different views. In coronal views, "left" and "right" are as if you were looking at a persons face; therefore "your right" is the coronal sections "left." In sagittal views the lower numbered sections are the right side, whereas the higher numbered sections are the left side. In axial views, you are looking from underneath upon the section; therefore "your right" is the axial sections "left."

Medial and Bilateral

All nodes/planes should be set bilaterally unless otherwise specified.

Location of Axial Nodes/Planes

All axial nodes/planes should be placed in a "medium depth" unless otherwise specified.

Coronal Series I

Plane I

The anterior tip of the genu of the corpus callosum. To identify plane I go to the anterior tip of curvature of the corpus callosum.
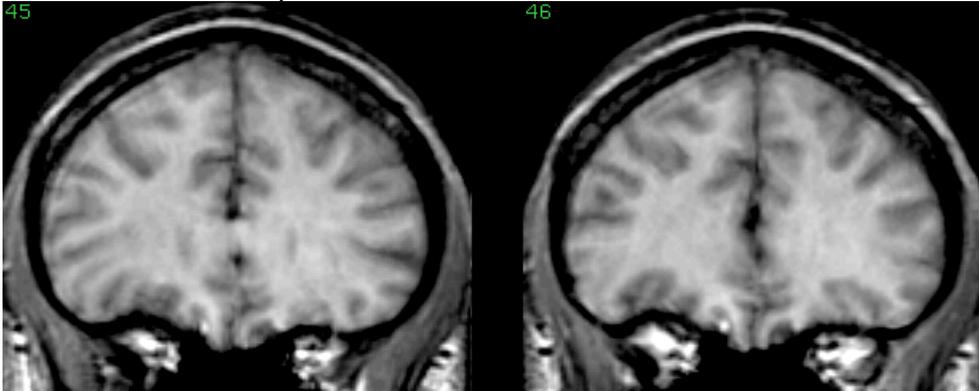
Click on the most rostral unequivocal decussation of the corpus callosum (not where there is just a thin tangentially cut film) at the level of the midline in the center of the corpus callosum. This plane is the same for both the left and right hemispheres.
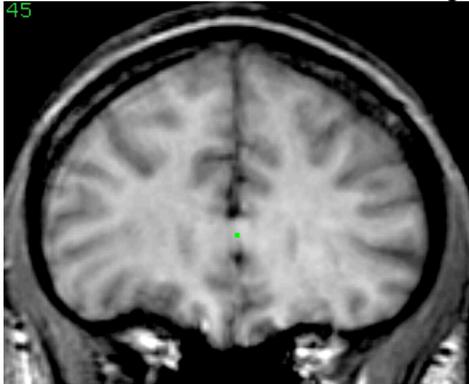
You should use the segmentation outlines to help you define this node. Load the segmentation outlines in TileDisplay by first typing in the segmentation prefix on the prefix line found in the upper-left corner of the menu column, and then clicking on the "OTL" button. by looking at the segmentation outlines you can see where the segmentor has already made the decision for you.

Ins-Ant

The anterior tip of the insula. Identify the most anterior coronal slice containing insula where there is full thickness of the insular cortex; you will notice that the insular cortex will begin to "dip down."
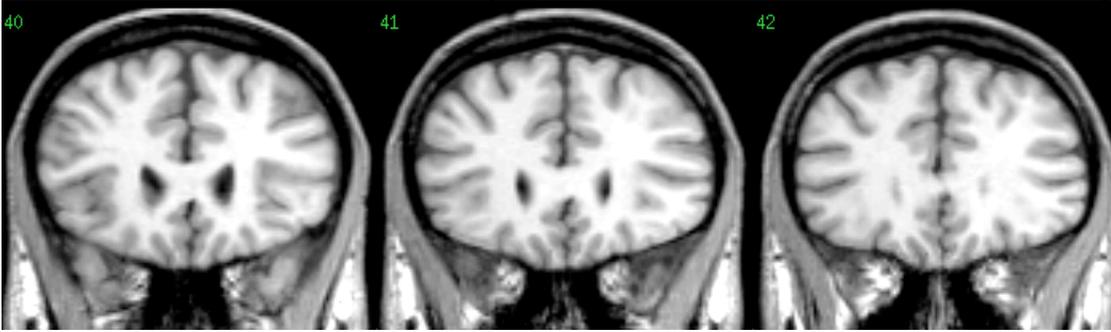
Click on the uppermost tip of the circular sulcus. Cross-reference your point in the sagittal view to be sure it lies within the circular sulcus.
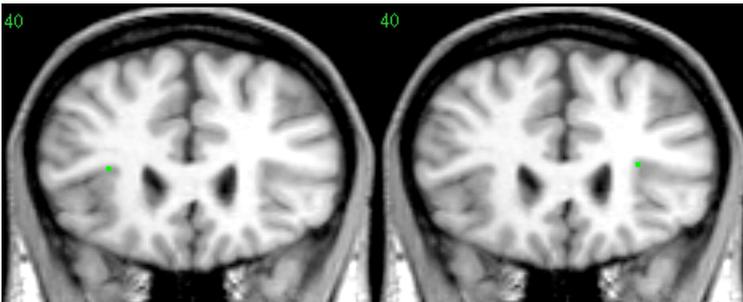
Septum

The posterior end of the septal nuclei. The septal nodal point indicates the border between subcallosal cortex and the vertical portion of the basal forebrain. Identify the most caudal plane with subcallosal neocortex. It will be close to the rostrum of the nucleus accumbens. Look for the distinct white matter line in the coronals, near the midline, in the same area as the nucleus accumbens. There must be a distinct cortical ribbon and subcortical white matter border in the slice you choose. It will also be near the anterior commissure.
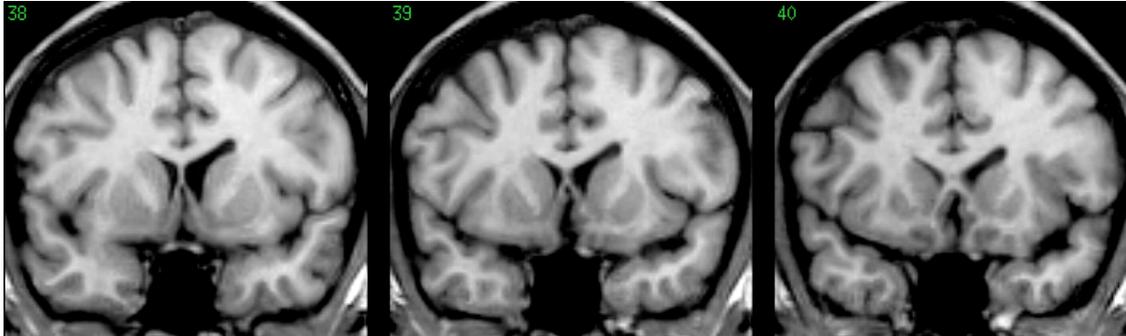
Click on the superior end of the cortex at the transition between the rostrum of the corpus callosum and cortex. This point is usually at the inferior border of the lateral ventricle.
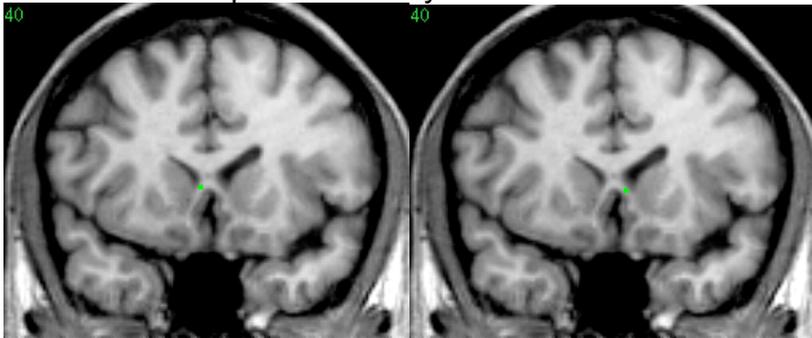
BASFRBRN

The caudal end of the orbitofrontal neocortex. The basal forebrain nodal point indicates the border between frontal orbital cortex (FOC) and the horizontal portion of basal forebrain. Identify the most caudal slice with visible orbitofrontal neocortex (it will be close to the optic chiasm). The slice must have a distinct cortical ribbon and subcortical white matter with explicit cortical-white matter border.
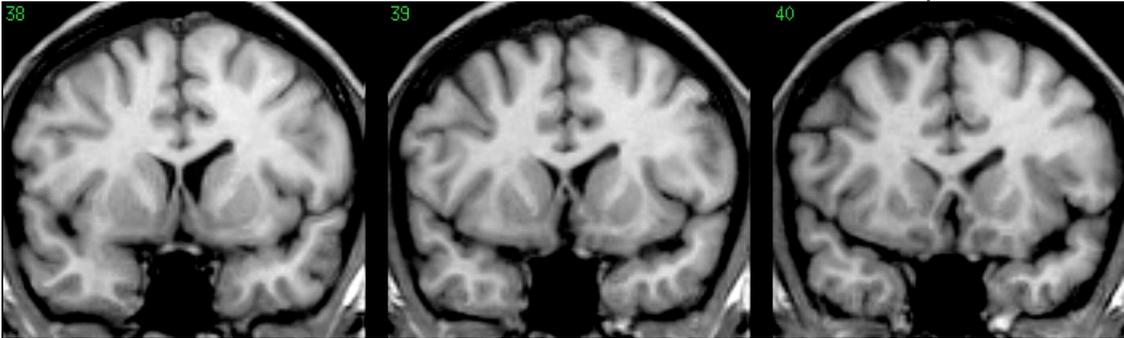

Click in the subcallosal gyrus that protrudes medially just below the septum. Usually this gyrus is at the medial-inferior corner of each hemisphere.
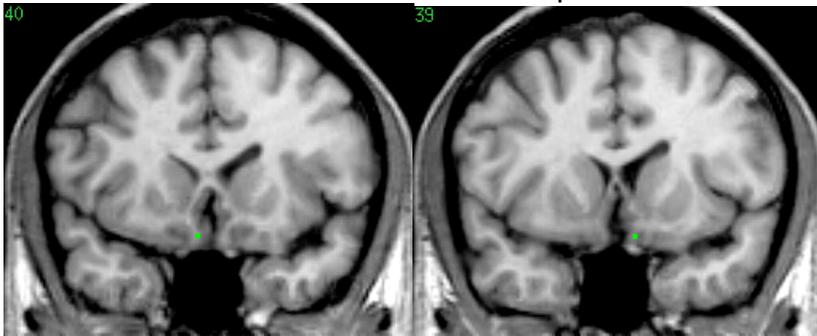
Plane B

The caudal border of the temporal pole. Identify the most caudal coronal slice with temporal pole before the frontal-temporal continuity.
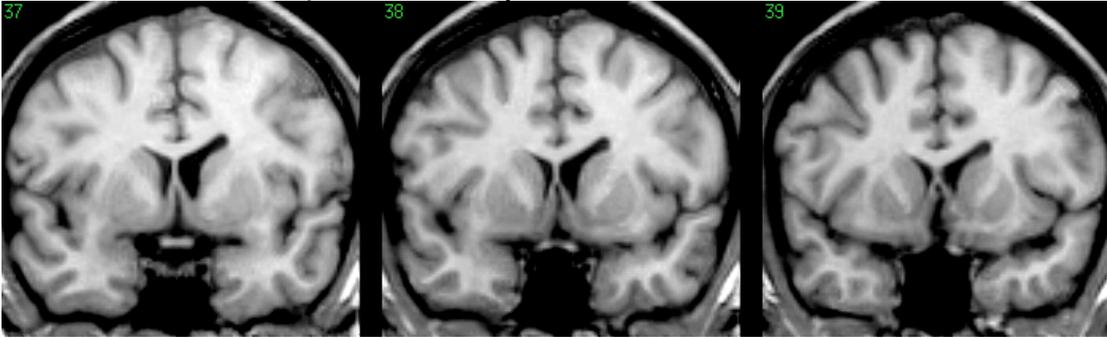
Click in the middle of the temporal lobe mass on this slice.
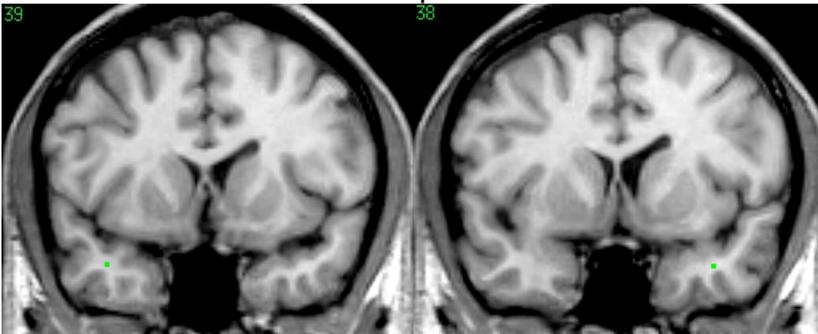
You should use the segmentation outlines to help you define this node. Load the segmentation outlines in TileDisplay by first typing in the segmentation prefix on the prefix line found in the upper-left corner of the menu column, and then clicking on the "OTL" button. by looking at the segmentation outlines you can see where the segmentor has already made the decision for you.

Plane J

Defined by the anterior commissure. This node is always given to you by the program.

Coronal Series II

Plane C

The most rostral level of the Heschl's gyrus. Identify the most anterior slice where there is a distinct strip of cerebral white matter that penetrates the thumb-like projection of the Heschl's gyrus. A discrete Heschl's fissure must be visible.
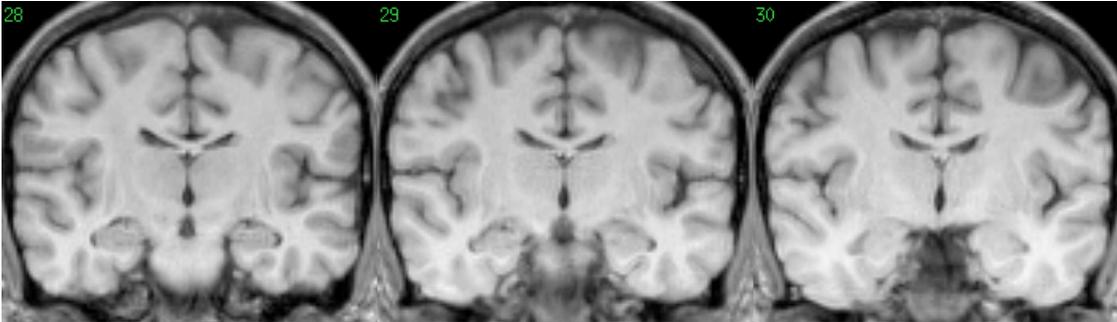

Click on the white matter stem within the Heschl's gyrus.
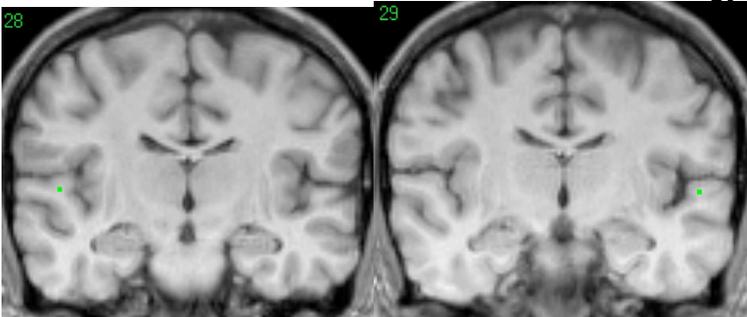
This point should not be in front of the anterior commissure.

He-Ant

The rostral tip of Heschl's fissure (the fissure on the lateral side of Heschl's gyrus). By convention, rostro-caudally identical to plane C. Go to the same coronal slice used to create the node for plane C.
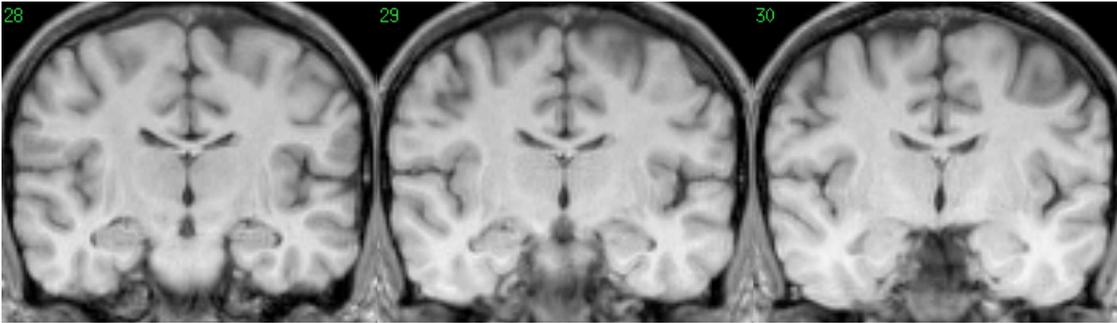

Click at the base of Heschl's fissure.
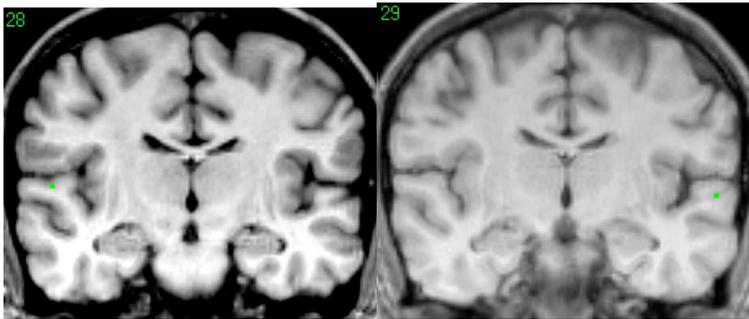
Plane M

The most rostral coronal slice containing full thickness of the lateral geniculate nucleus (LGN). Identify the coronal slice with the largest and most rostral visible LGN. This will be near the posterior commissure.
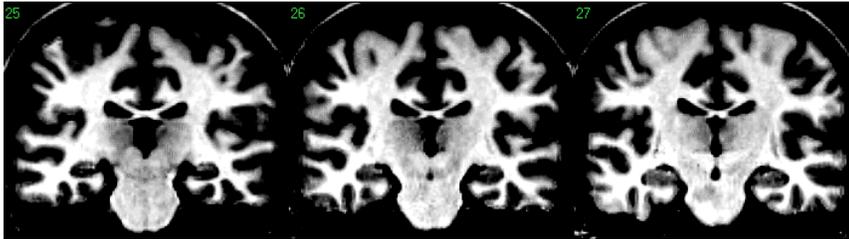
### Adjusting Brightness

To get the best visibility of LGN, adjust the brightness by clicking the middle mouse button.
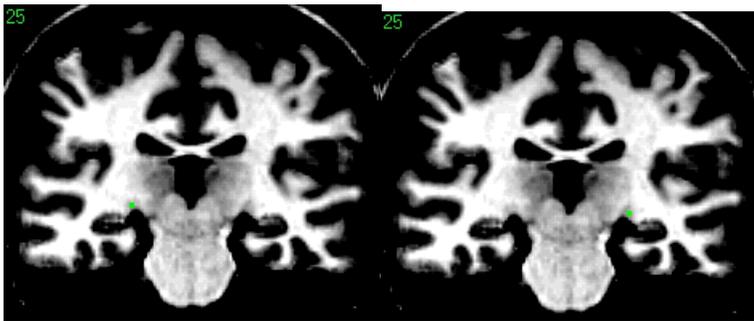

Click in the middle of the LGN to create node.

He-Pos

The posterior tip of the Heschl's fissure. By convention, rostro-caudally identical to Ins-Pos. Identify the most caudal slice where there is a distinct Heschl's fissure.
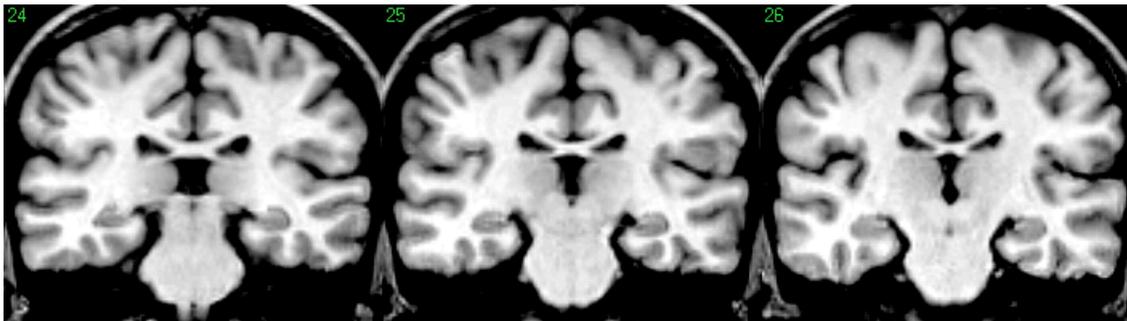

Click at the base of the Heschl's fissure.
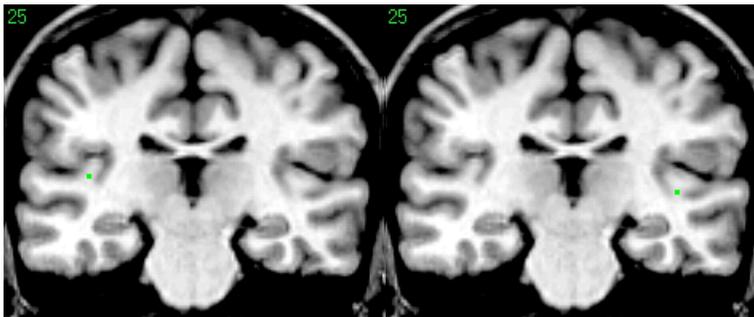
Frt-Pos

The posterior tip of the first transverse fissure (the fissure that lies on the medial side of the Heschl's gyrus). By convention, rostro-caudally identical to Ins-Pos and He-Pos. Identify the most caudal slice where there is a distinct first transverse fissure.
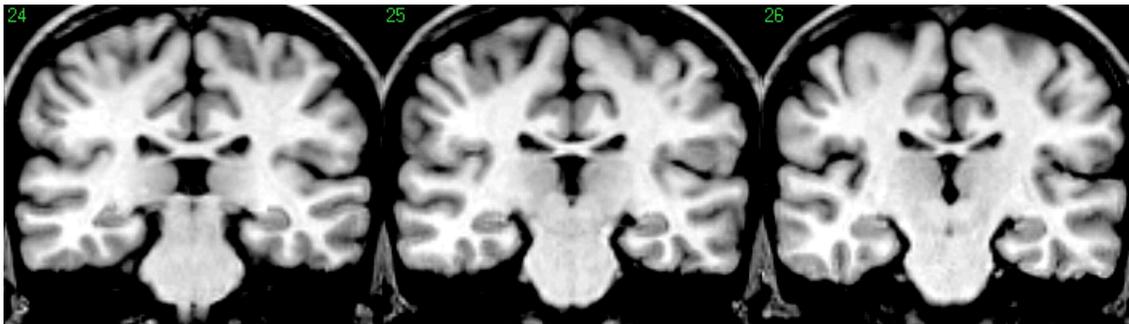
Click at the base of the fissure.
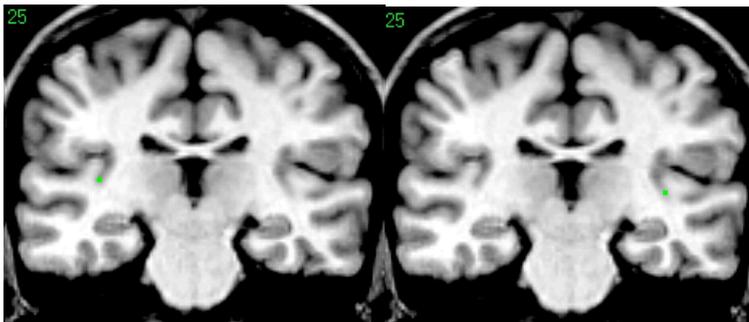
Ins-Pos

The posterior tip of the Insula. By convention, rostro-caudally identical to He-Pos and Frt-Pos. Identify the most caudal slice where there is a distinct first transverse fissure.
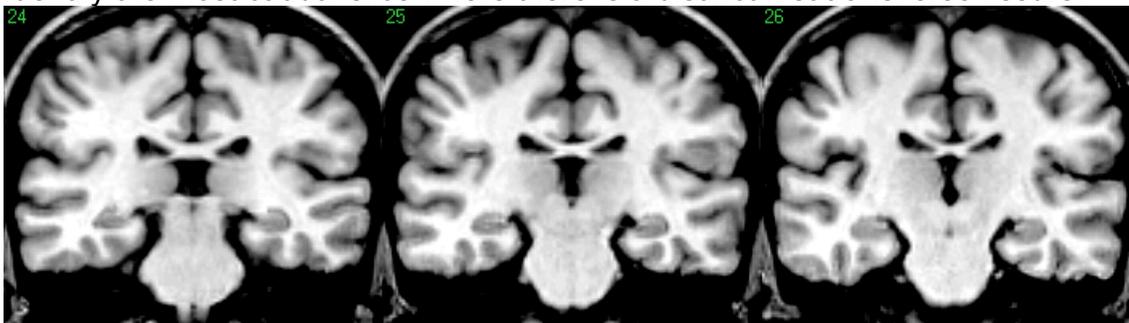
Click on the uppermost tip of the vertical insula.
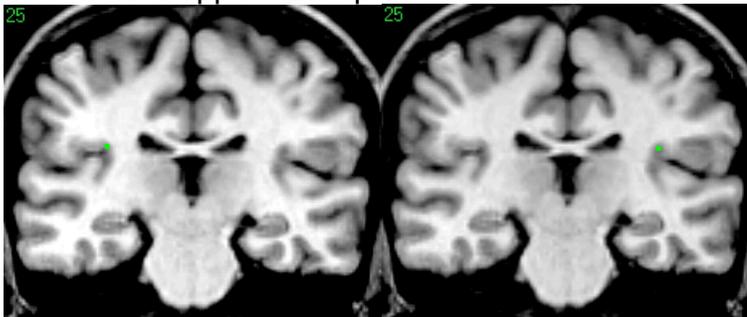
Cross-Reference this point in sagittal sections where you will see the point in the posterior most portion of the insula.

Coronal Series III

Plane D

This plane is defined by the end-point of the sylvian fissure. It is the anterior border of the temporoparietal transition zone on the lateral brain surface and of the occipitotemporal transition zone on the lateral and ventral brain surfaces. Also, the most caudal level containing the planum temporale (PT).   Identify the most caudal coronal slice including full thickness cortex for the PT.
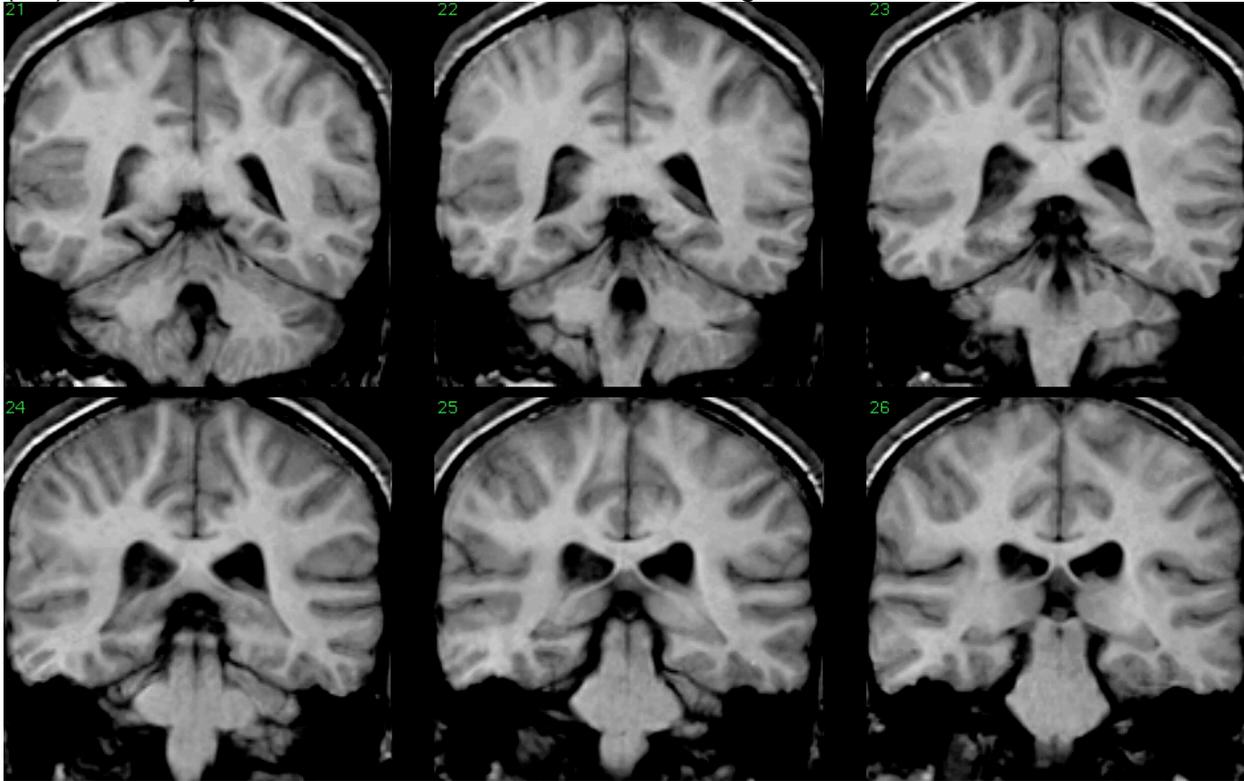
Click in the sylvian fissure at its hemispheric margin.
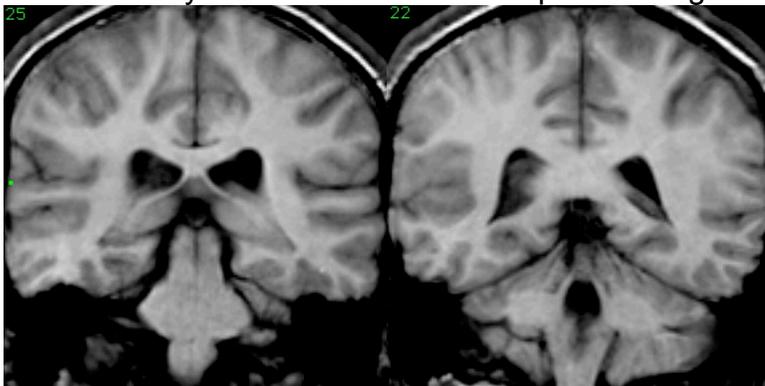
Plane N

The rostral tip of the calcarine sulcus. Identify the most rostral slice where the calcarine fissure has a distinct indentation and there is a distinct calcarine cortex.
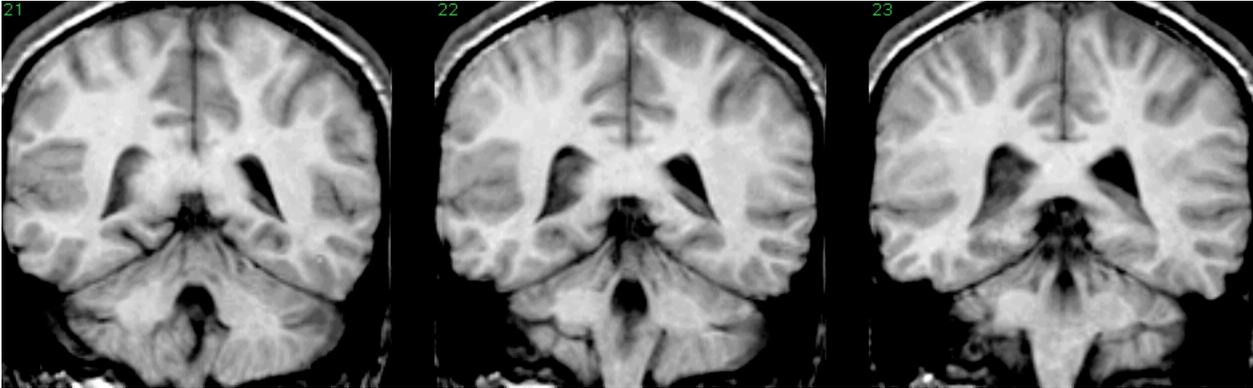
Click in the calcarine sulcus at the medial hemispheric margin.
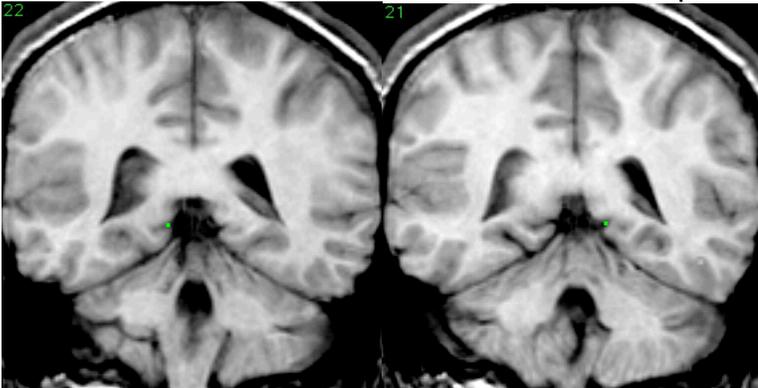
Splenium

The most caudal corpus callosum connection. Identify the most caudal coronal slice where there is unequivocal decussation of the corpus callosum (not just a thin tangentially cut film).
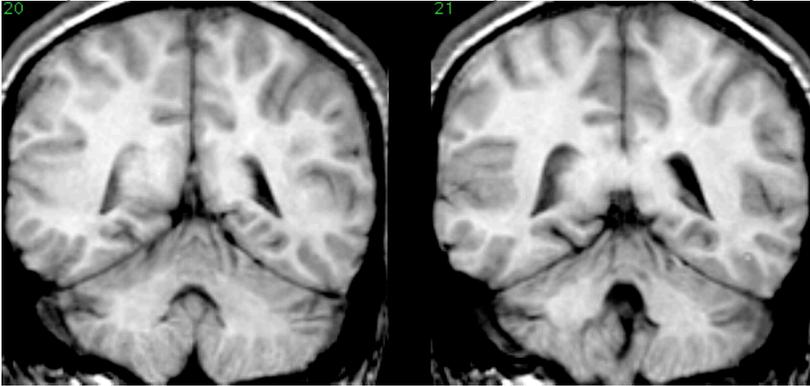

Click in the middle of the corpus callosum. This node is the same for both the right and left hemispheres.
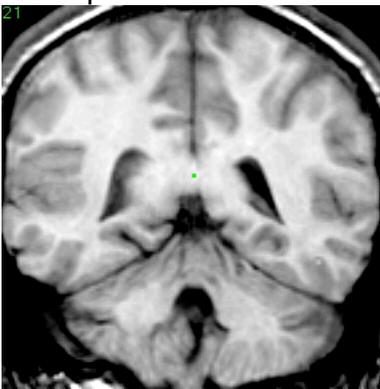
You should use the segmentation outlines to help you define this node. Load the segmentation outlines in TileDisplay by first typing in the segmentation prefix on the prefix line found in the upper-left corner of the menu column, and then clicking on the "OTL" button. by looking at the segmentation outlines you can see where the segmentor has already made the decision for you.

Plane F

The point where the intraparietal sulcus opercularizes (twisting back, snake-like folding). Usually, the parietooccipital sulcus opercularizes also. Often, the opercularized intraparietal and parietooccipital sulci mirror each other. Follow the intraparietal sulcus caudally until it begins to opercularize . There must be a distinct parieto-occipital fissure present in the slice that you choose. Be sure to check the sagittal view as well.
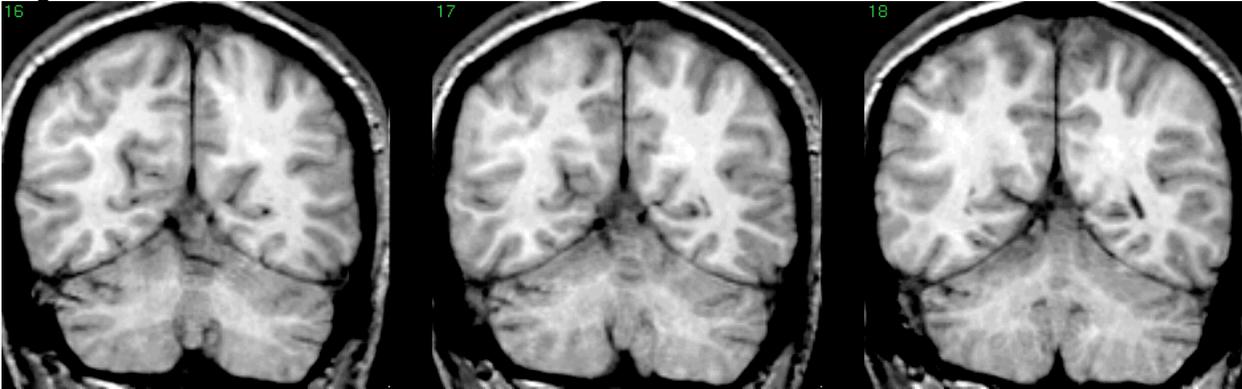
Click in the middle of the white matter between the opercularized intraparietal and the most lateral portion of the parietooccipital sulcus in the first slice with parietal opercularization. Check to make sure that your choice isn't so close to the Jensen's that you no longer have angular gyrus.
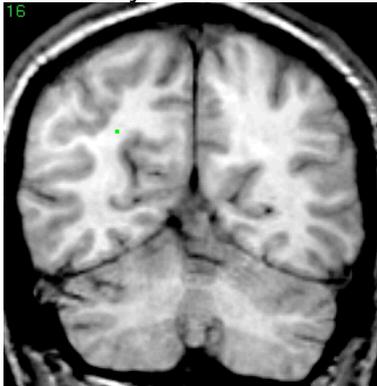
Coll-Pos

The most caudal plane of the collateral fissure. Follow the collateral fissure caudally. Identify the most caudal slice where you see the collateral fissure with a discrete cortical-white matter junction (full thickness cortex is visible) and click in the collateral fissure at its hemispheric margin. If the collateral fissure bifurcates, take the most medial portion.

Axial Series

SF-Prc

The intersection of the superior frontal sulcus and the precentral sulcus. Go to the centrally located axial slices that contain the superior frontal sulcus. Identify the transaxial slice where the precentral and superior frontal sulci intersect.
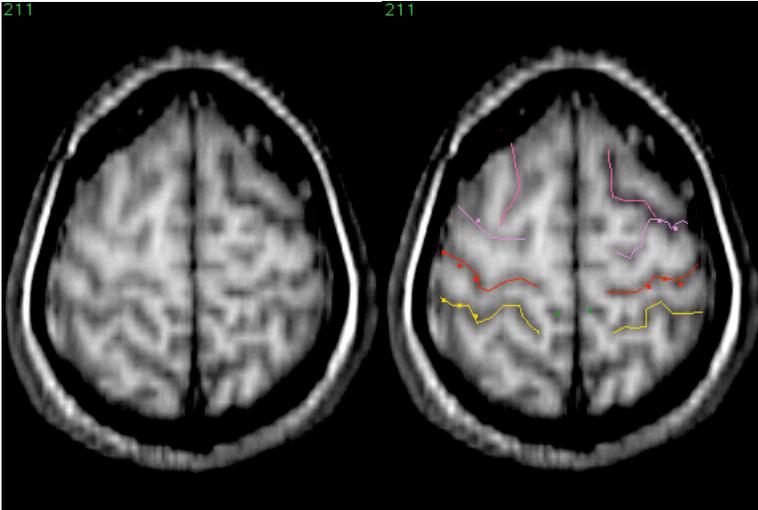
Click within the grey shoulder of the precentral sulcus.
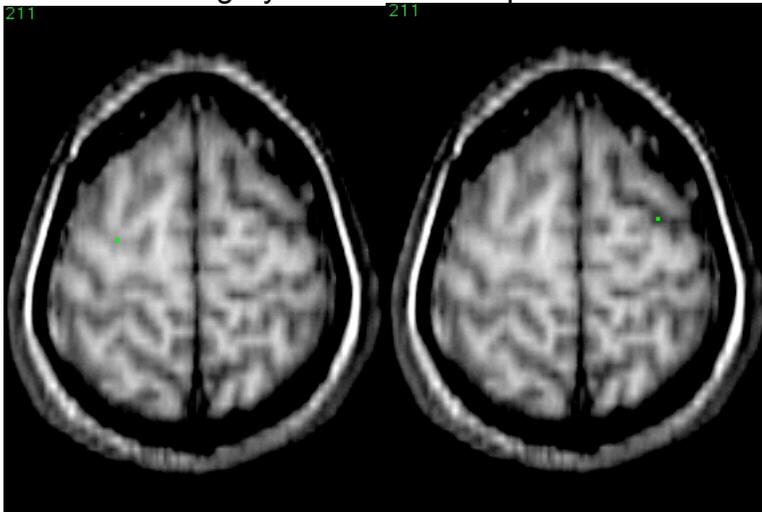
Plane K

The dorsal end of the precentral sulcus. Identify "high" in transaxial slices where the precentral sulcus meets the medial hemispheric margin.
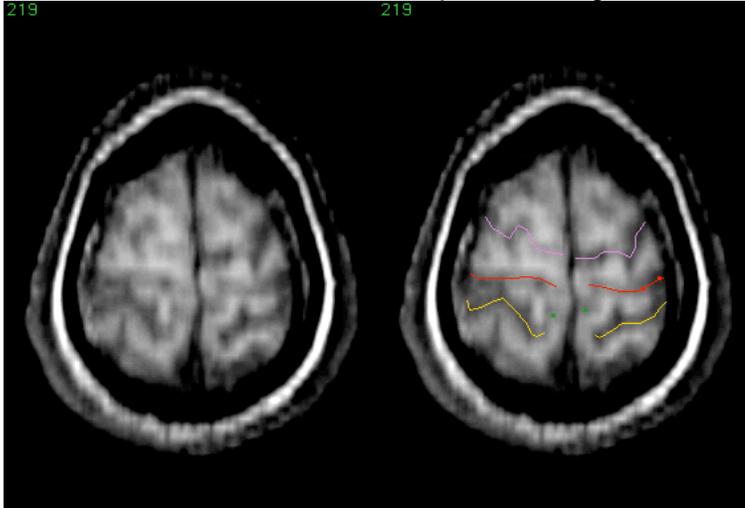
Click in the precentral sulcus at this point. You can verify this point by tracing it downward.
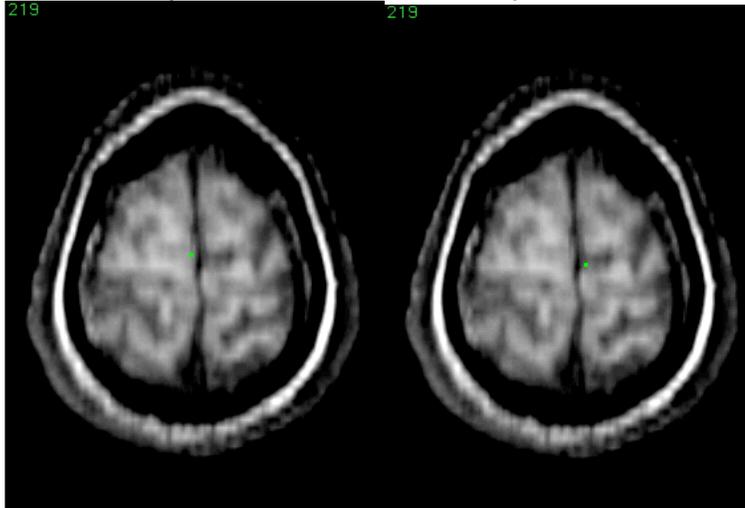
If the precentral sulcus does not hit the medial hemispheric margin, take the node at its most medial extent.

Omega M

This is a special node that is not used in general parcellation. Leave this node blank.

Omega L

This is a special node that is not used in general parcellation. Leave this node blank.

Plane L

The dorsal end of the central sulcus. Identify "high" in the transaxials where the central sulcus meets the medial hemispheric margin.
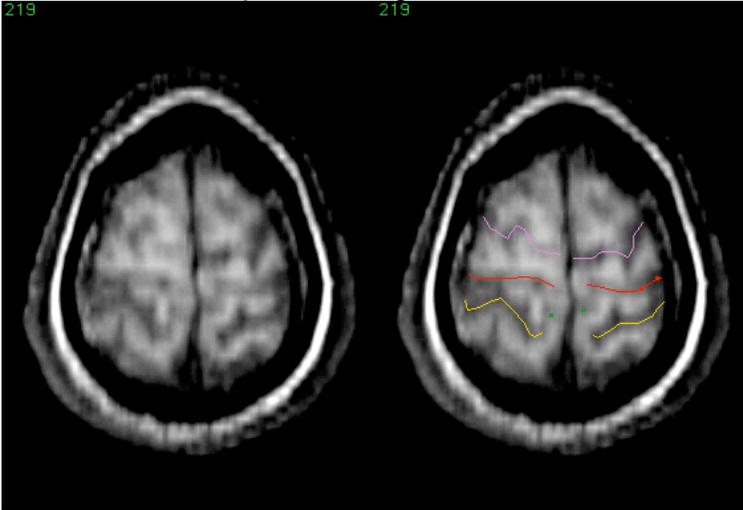
Click in the central sulcus at this margin.
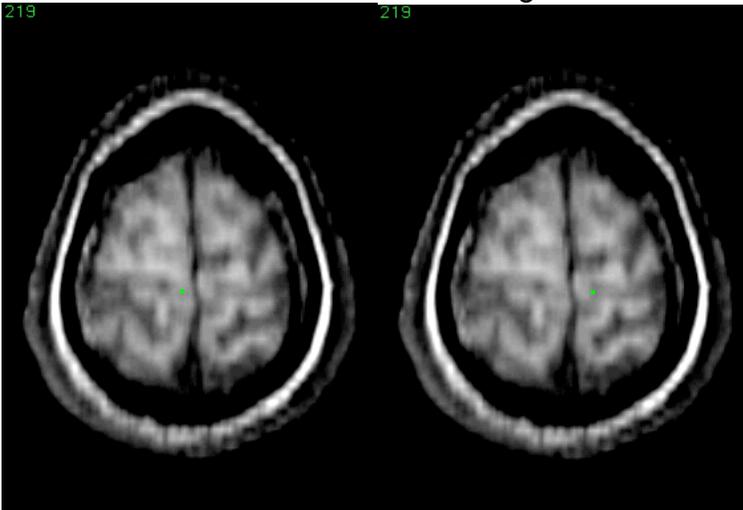
If the central sulcus does not hit the medial hemispheric margin, take the node at its most medial extent.

Poc-Hm

The dorsal end of the postcentral sulcus. Identify "high" in the transaxial slices where the postcentral sulcus meets the medial hemispheric margin. This point should not go beyond the transverse parietal sulcus.
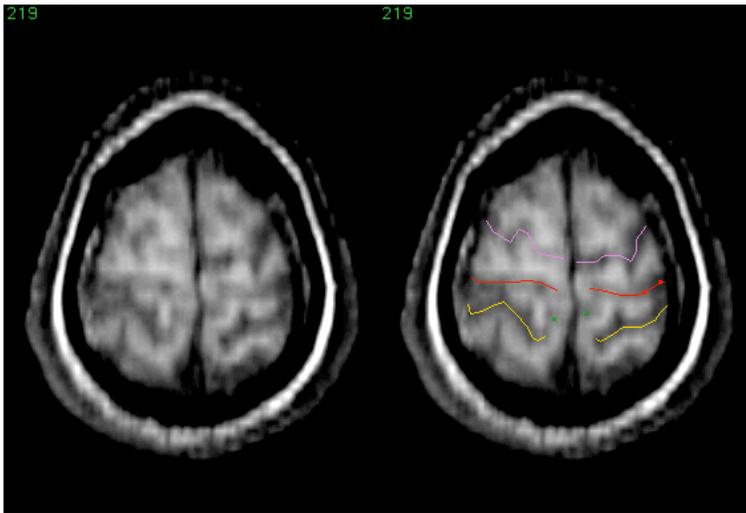
Click in the sulcus at this point.
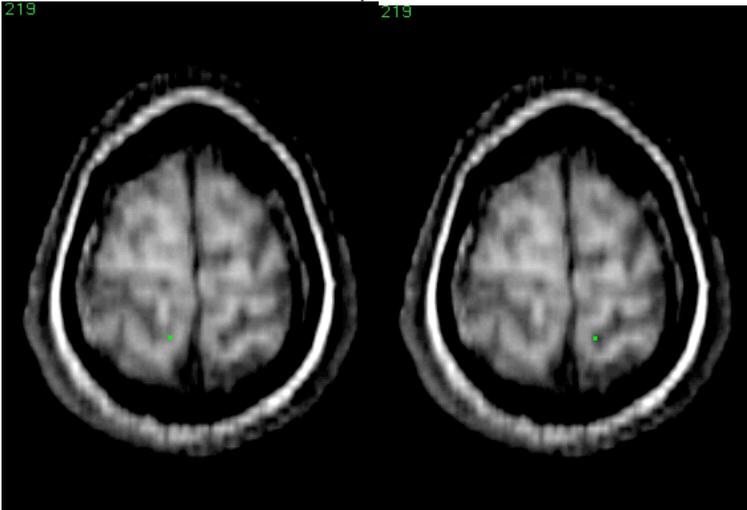
If the postcentral sulcus does not hit the medial hemispheric margin, take the node at its most medial extent.

Poc-Inpar

The intersection of the postcentral and the intraparietal sulci.
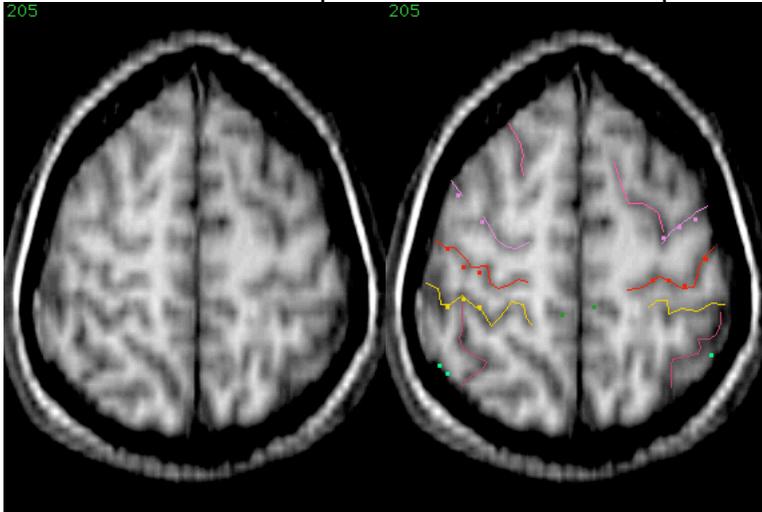
Click on the point of intersection of the postcentral and intraparietal sulci.
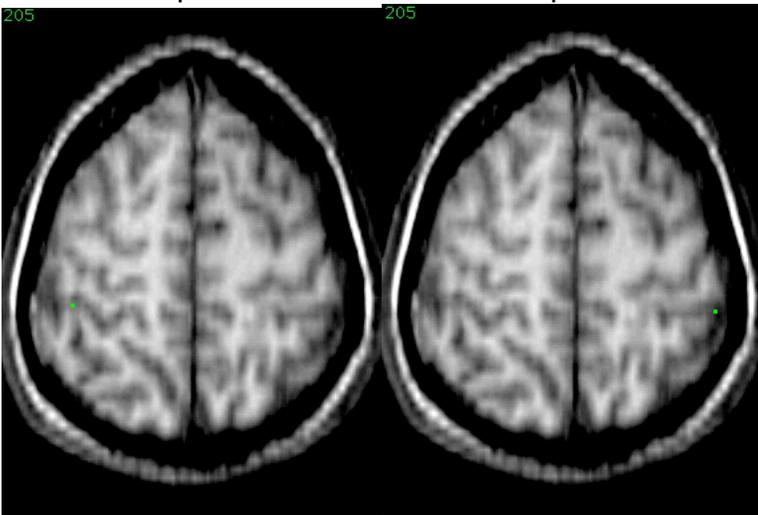
IJ-Inpar

The intersection of the intermediate sulcus of Jensen and the intraparietal sulcus.
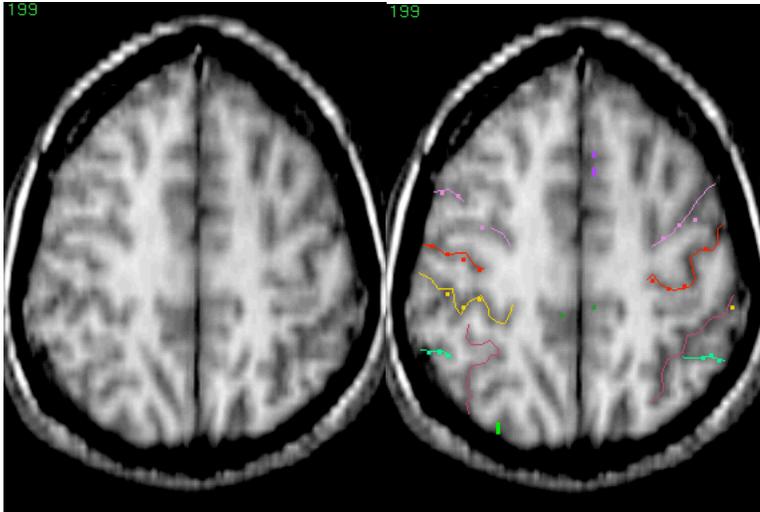
Click on the point of intersection of the intraparietal and Jensen's sulci.
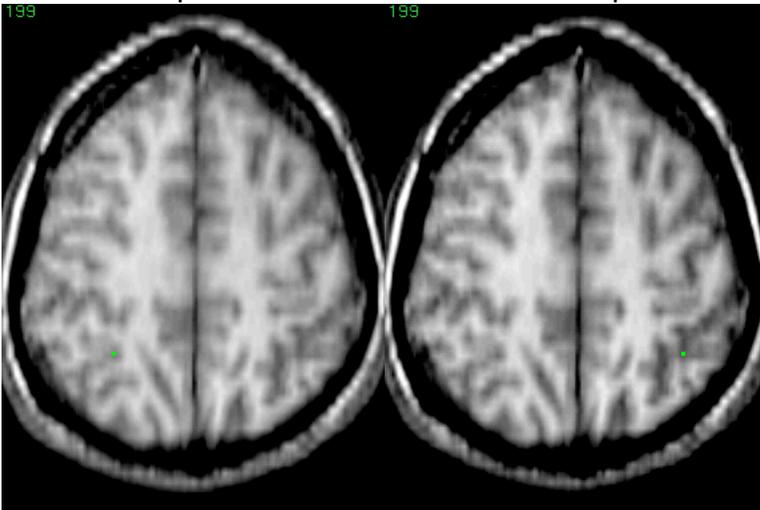
If Jensen's sulcus doesn't hit the intraparietal sulcus, click on the parietal sulcus in the same coronal plane as the point where the Jensen's sulcus ends.

Midsagittal Series I

Plane H
The anterior tip of the paracingulate sulcus.
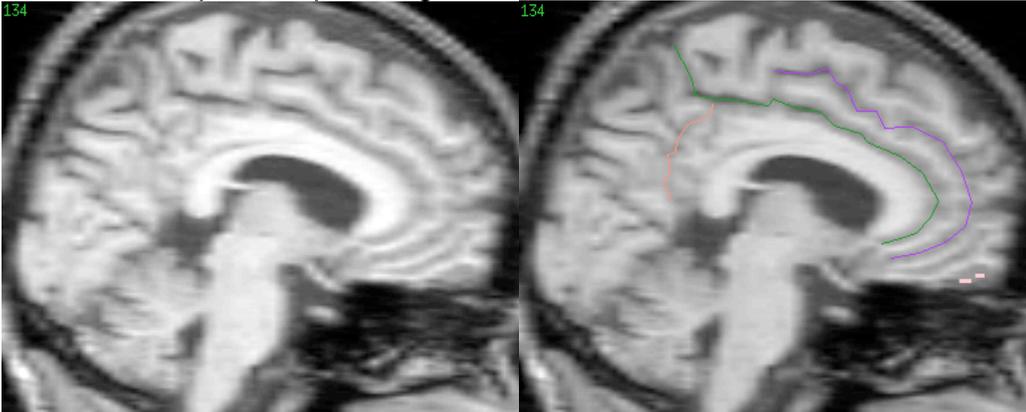
Click on the most anterior tip of the smooth curvature of the paracingulate sulcus
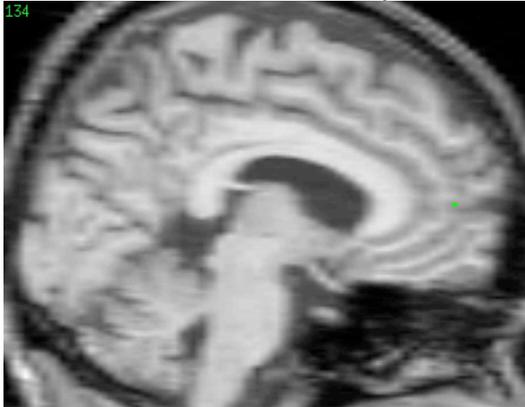
Ci-Ant

The anterior border of the cingulate sulcus.
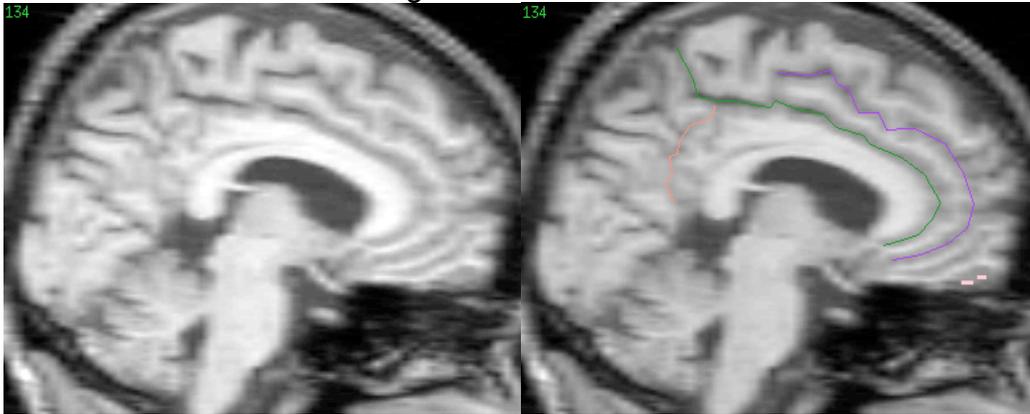
Click on the most anterior tip of the cingulate sulcus in the mid-sagittal view.
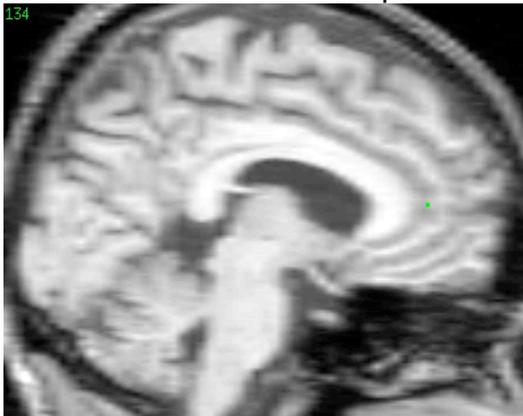
Sp-Ci

The intersection of the subparietal sulcus and the cingulate sulcus. Identify the mid-sagittal slice where the subparietal and cingulate sulci intersect at their lowest point.
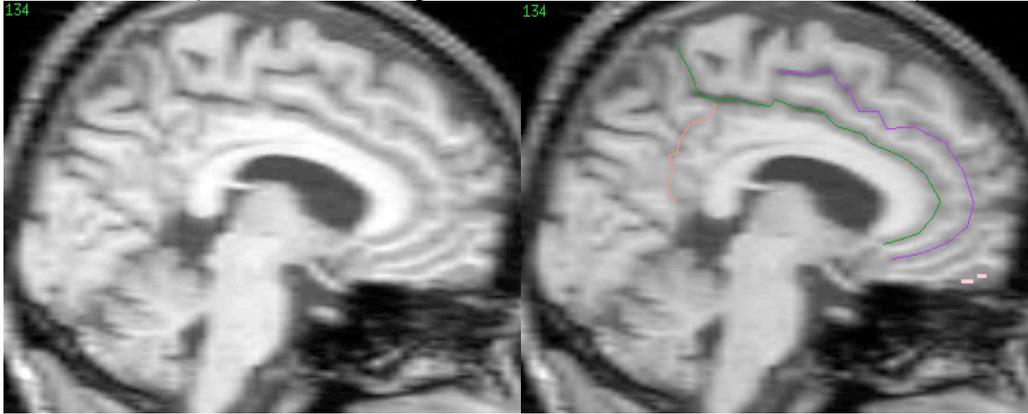
Click on this intersection.
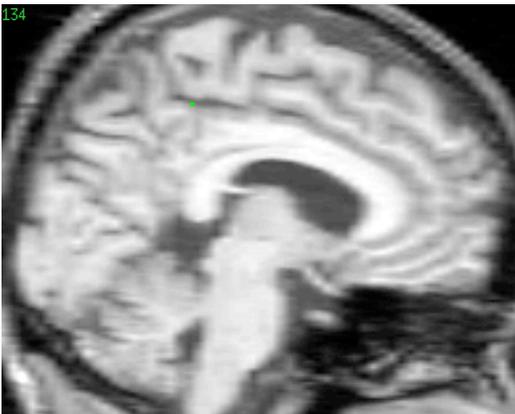
If they do not quite intersect, follow the subparietal to the extent it can be distinguished and go vertically to the cingulate to click.

Sp-Calc

The intersection of the subparietal and calcarine sulci.
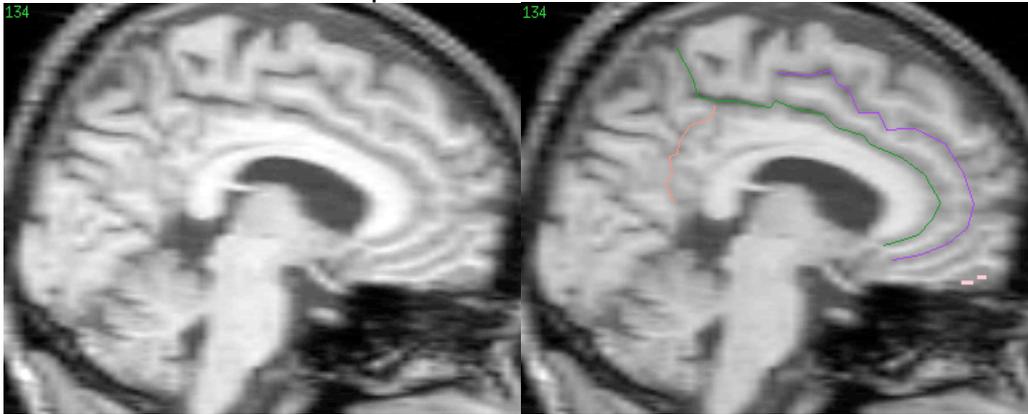
Click on the point of intersection of the subparietal and calcarine sulci.
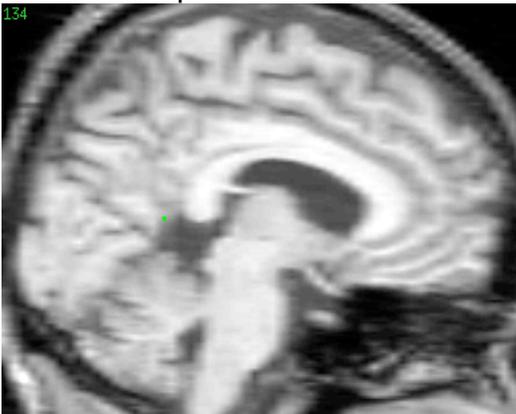
If there is not a visible point of intersection, then click on the lowest tip of the vertical portion of the subparietal sulcus.

Midsagittal Series II

CunPnt

The intersection of the parietooccipital sulcus with the calcarine sulcus.
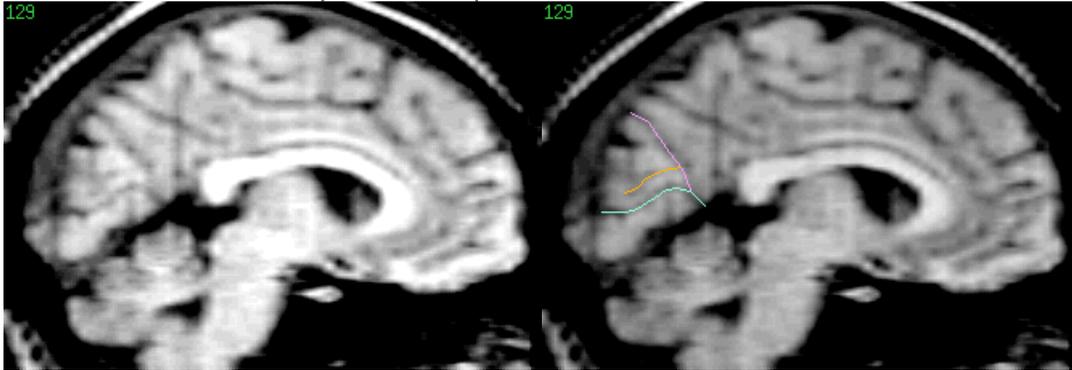
Click on the junction of the calcarine and parietooccipital sulci.
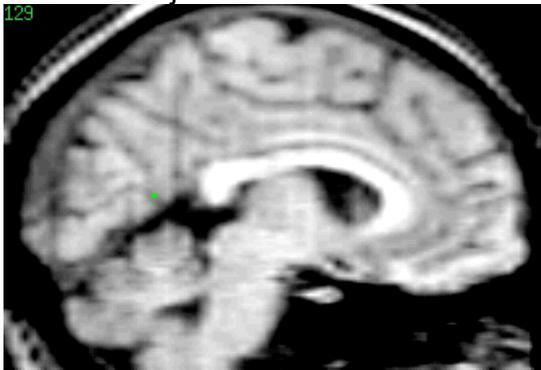
Cun-Po

The intersection of the cuneal and the parieto-occipital sulci. Generally, the cuneal sulcus is visible in multiple mid-sagittal slices.
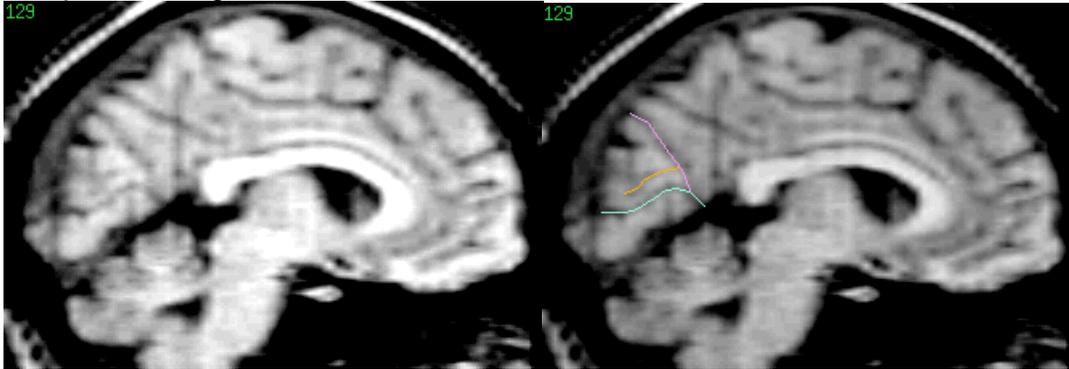
Click on the junction between the cuneal and parieto-occipital sulci that is located centrally in the slices where the cuneal sulcus is visible. Click within the gray shoulder of the parieto-occipital sulcus at this point of junction.
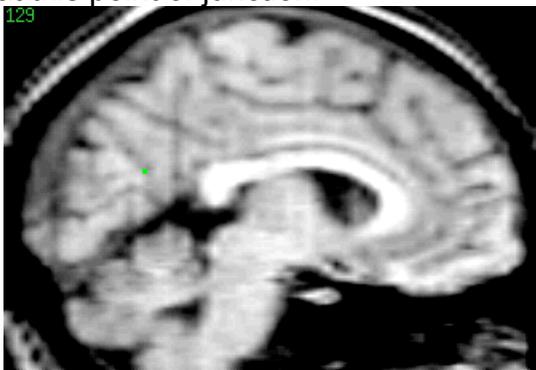
Po-Hm

The point where the parietooccipital sulcus extends to the hemispheric margin.
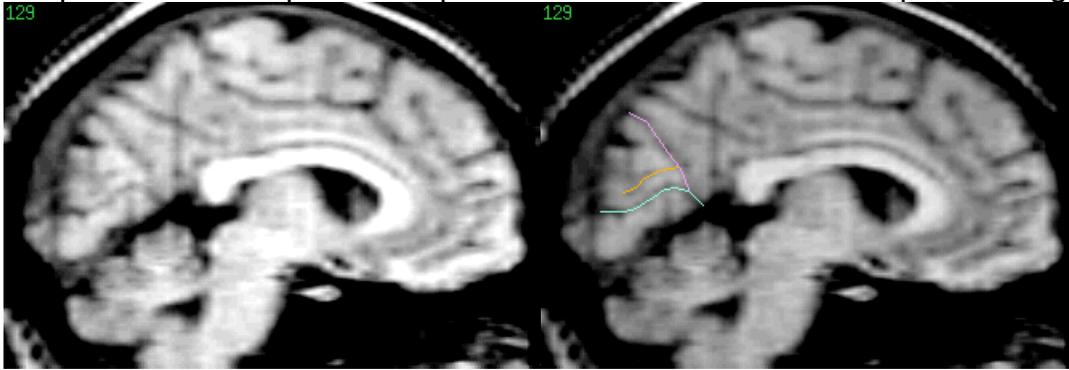
Click within the parietooccipital fissure at the hemispheric margin where parietooccipital sulcus extends to this margin completely.
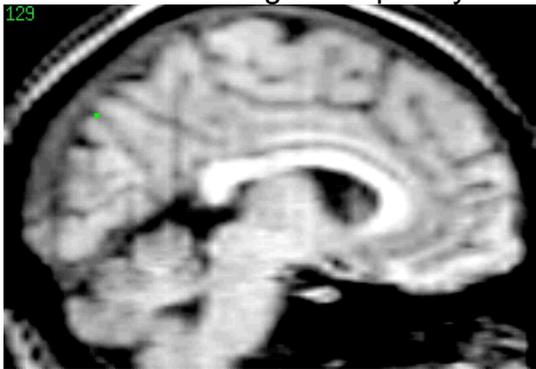
Plane G

The caudal tip of the cuneal sulcus. Click in the most caudal end of the cuneal sulcus where there is still visible full thickness cortex.

This plane should be cross-referenced in a coronal view.

Lateral Sagittal Series I

Plane A
The rostral end of the anterior horizontal ramus of the sylvian fissure.
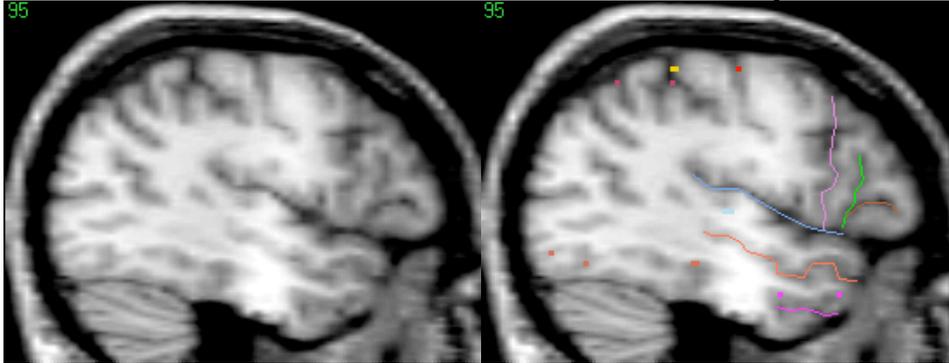
Click on the most rostral tip of the anterior horizontal ramus of the sylvian fissure that has visible full thickness cortex.
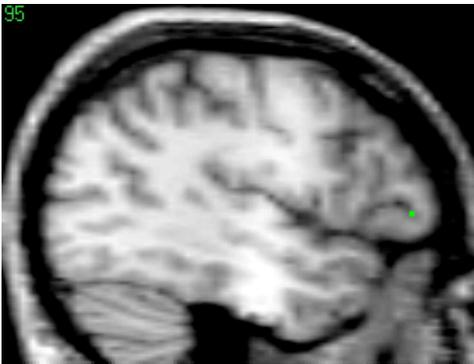
This plane should be cross-referenced in the coronal view. Look for a sulcus that is continuous with the top of the insula.

Ahr-Syl

The caudal end of the anterior horizontal ramus of the sylvian. Identify the caudal end of the anterior horizontal ramus of the sylvian in lateral sagittals, it will be at the junction of the anterior horizontal sylvian and the posterior horizontal or anterior ascending sylvian. Click at the most caudal point of the anterior horizontal Sylvian.
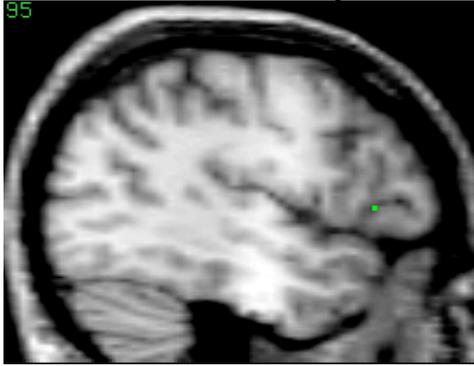
Aar-Syl

The point where the anterior ascending ramus of the sylvian joins with the horizontal portion of the sylvian.
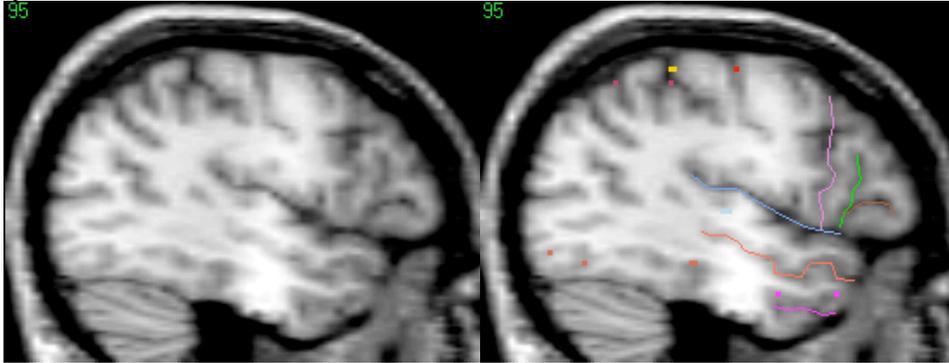
Click at the junction of the anterior ascending ramus of the sylvian and the horizontal sylvian.
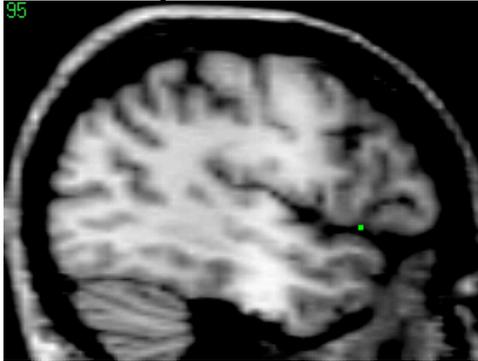
Aar-lf

The superior tip of the anterior ascending ramus of the sylvian.
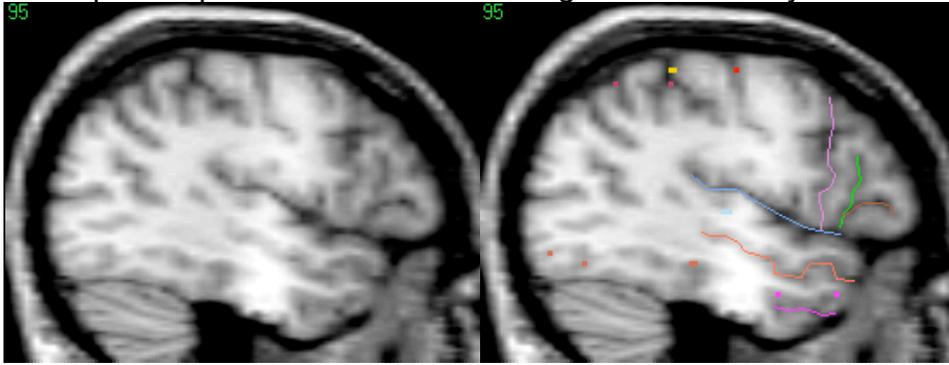
Click at the point of intersection of the anterior ascending sylvian and the inferior frontal sulcus.
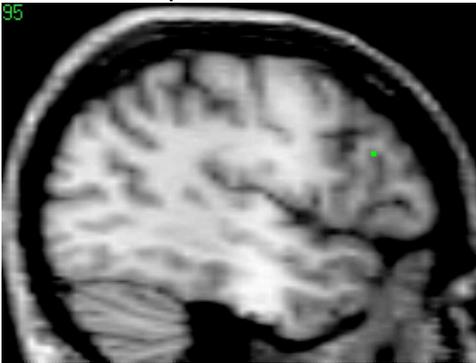
If the inferior frontal sulcus is not visible, then click at the superior tip of the anterior ascending ramus of sylvian fissure.

Lateral Sagittal Series II

If-Prc

The intersection of the inferior frontal sulcus with the precentral sulcus.
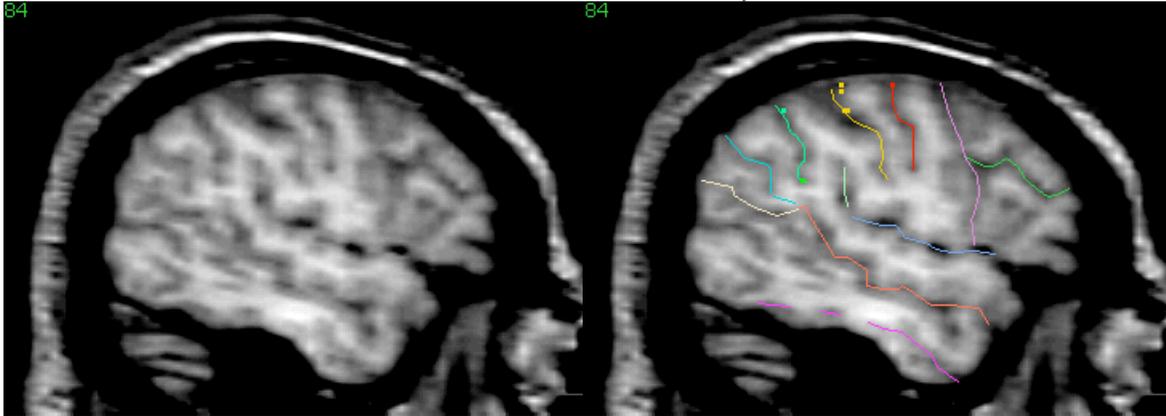
Identify the central portion of the inferior frontal sulcus and click at its junction with the precentral within the anterior grey shoulder of precentral sulcus . Verify the stability of this point over several levels.
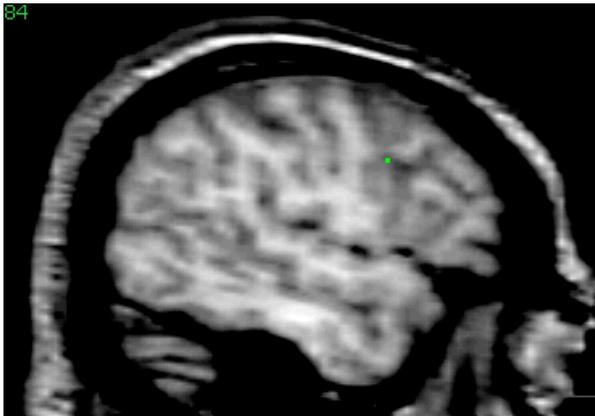
Plane O

The point where the precentral sulcus hits the sylvian fissure.
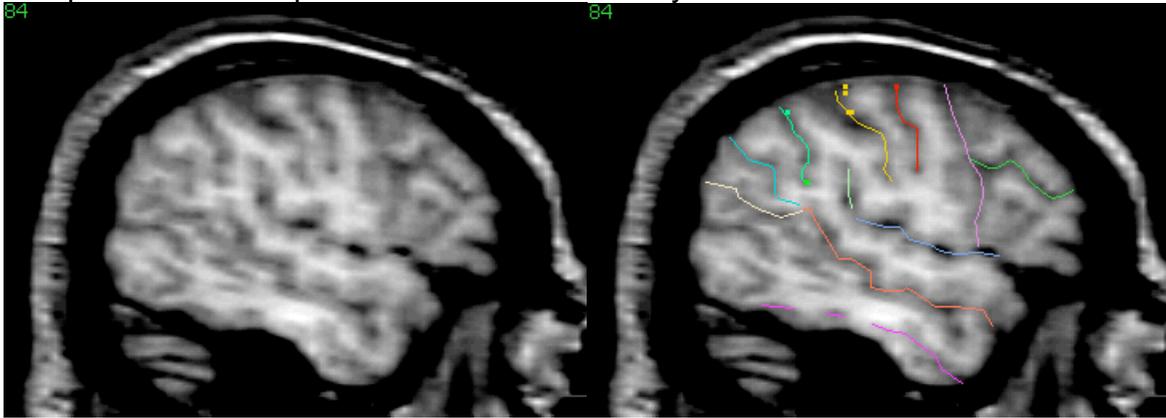
Click on the most lateral point of precentral-sylvian intersection and verify this by tracing medially.
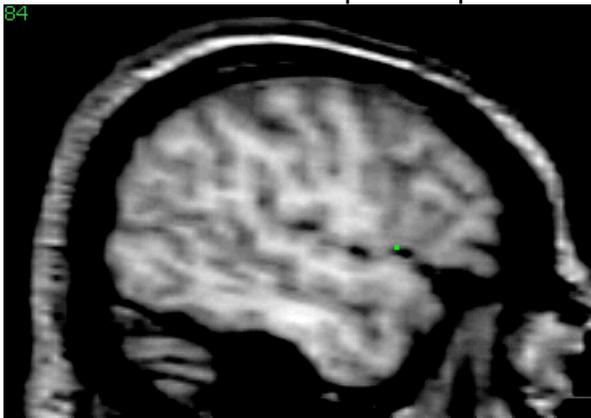
If the precentral sulcus does not hit the sylvian fissure, set the plane at its most inferior point.

Ce-Syl

The point where the central sulcus hits the sylvian fissure. Identify the most lateral point of the central and sylvian intersection and verify by tracing medially.
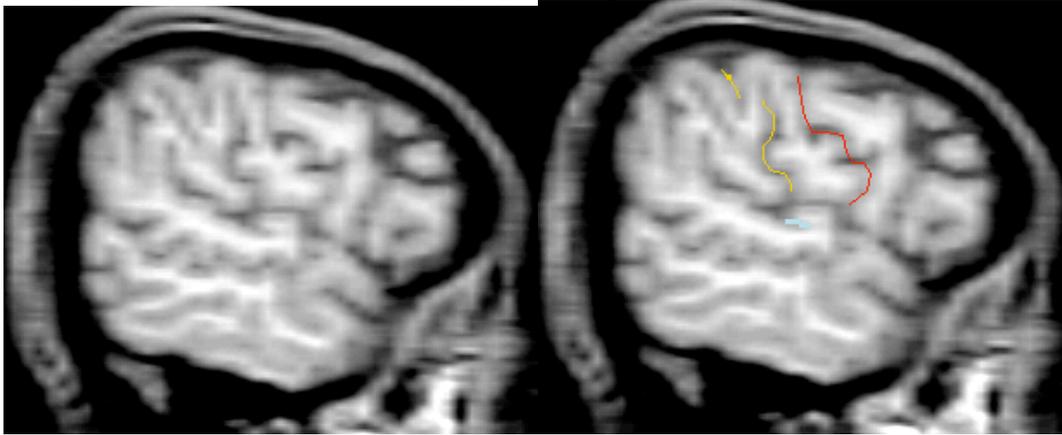
Click in the central sulcus at the point of ce-syl intersection.
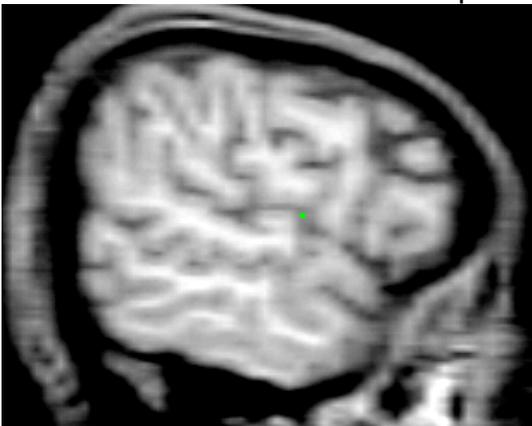
If the central sulcus does not hit the sylvian fissure, set the node at its most inferior point.

Plane P

The point where the postcentral sulcus hits the sylvian fissure.
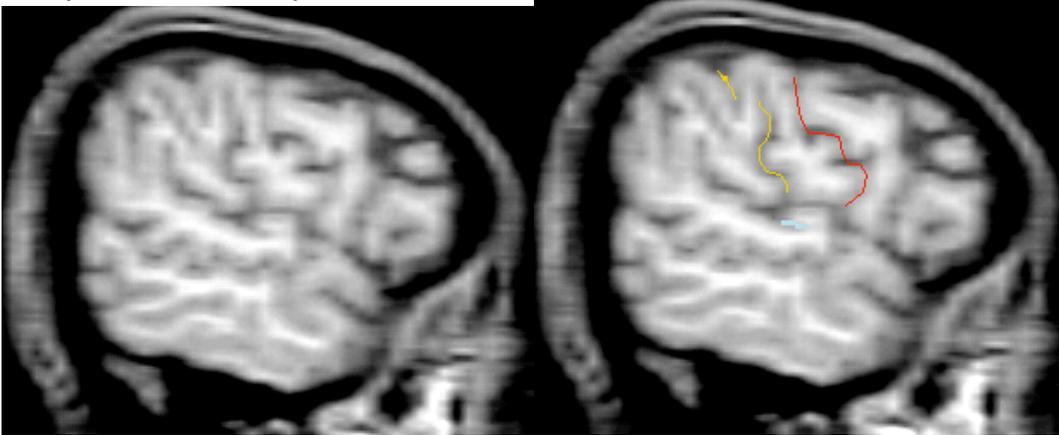
Click on the most rostral point of postcentral- sylvian intersection.
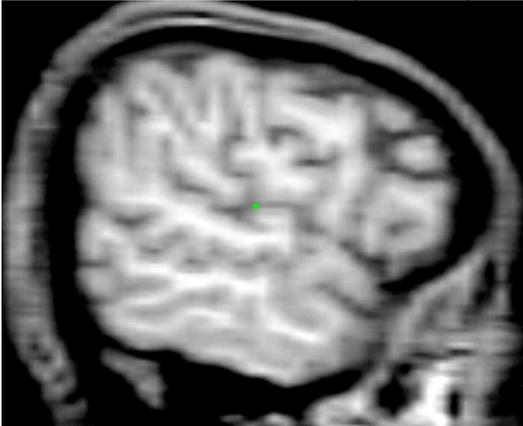
If the postcentral sulcus does not hit the sylvian fissure, set the plane at its most inferior point.

Plane E

The inferior end of the intermediate sulcus of Jensen. Identify Jensen's fissure in the gap between the angular and postcentral fissures.
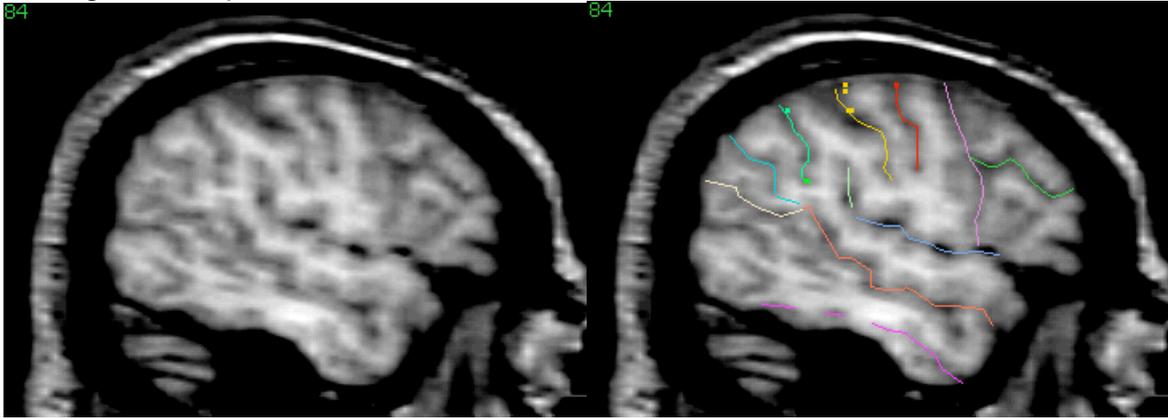
Click on the most inferior end of the Jensen fissure.
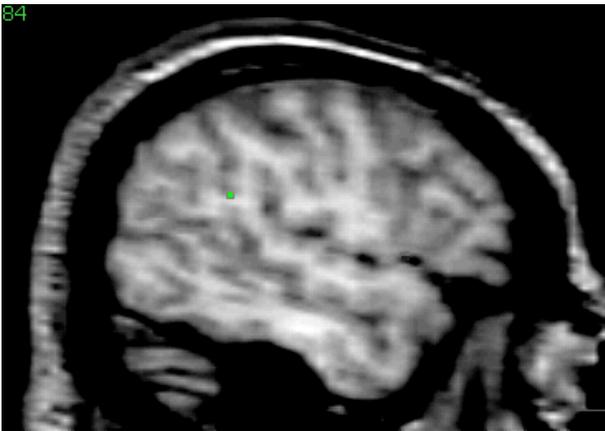
Parcellation Labels

Once the fissures and nodes have been assigned, the cortical ribbon can be divided into the separate parcellation units.

Using the Parcellation Menu Box
Go into Tile Display. Click on the box adjacent to the "label" icon near the bottom of the menu column. The parcellation menu box (parc box) will appear in the upper left corner of the window and a series of coronal slices will appear in the tile display. Segmentation outlines and sulci lines will be overlayed on the images.

In the parc box, the active coronal slice is indicated at the top of the right-hand column and in the middle of the left column.

Changing Slices
Use the "+", "-" icons to scroll through the coronal slices.

The right-hand column indicates which parcellation units should be included on the active slice, in both the right and left hemispheres, according to the nodes that were set. An "R" is at the top of the column when the right hemisphere units are shown, an "L" when the left hemisphere units are shown.

Parcellation lines must be drawn to divide the cortex into its separate units. We will refer to these lines as "parc lines." Parc lines are drawn the same way as sulci lines using the "parc" color from the color menu. These lines should follow the course of a fissure on the coronal plane from the exterior margin to the white matter, completely splitting the cortical ribbon.

The parcellation diagrams are useful (perhaps necessary) tools for deciding where to place parc lines. Refer to them often when learning the system as they help formulate a 3D knowledge of the parcellation units. Another great tool that should be used in conjunction with the diagrams for delineating the units of the cortex is the alternate cardviews configuration. The alternate configuration allows easy, convenient access to the cross-referential tools available in cardviews.

Using the Alternate Configuration View
Start by clicking on the ALT CFG button in the Parcellation Menu Box. The view will change allowing you to cross reference points much like in the standard CardViews environment. You can access all of the Parcellation Menu Box functions in this view. An important addition in this view is the list of slices on the left side of the screen. This lists the slices where many sulci have been drawn in the various views. By clicking on any of the boxes containing a slice number, you will be brought to that slice in the main view. Most of the parcellation procedure should be done in the alternate configuration mode. To return to Tile Display click on ALT CFG again.

Once the parc lines are drawn, the slice can be extracted and labeled.

Defining Parcellation Units

Click on the "SAVE EXTR LOAD" icon in the parc box. After a few seconds, the slice will be ready to label and the parc box will display more options. An enclosed parcellation unit will be highlighted on the active slice. To label the unit, identify its name in the parc box menu and click on the name with the left mouse button (if the name is already highlighted in the menu, you can click the middle mouse button). When the unit is labeled, it will be color-coded and another unit will be highlighted. Repeat this procedure for both hemispheres until the entire cortical ribbon is labeled.

Saving Defined Parcellation Units

Save parcellated slices by clicking on the "SAVE" icon in the parc box.

Using the Match Function

Often, the labeling process can be quickened by using the "match" function. If a parcellation unit and its corresponding label are both highlighted and the remaining labels are printed in green rather than white, the hemisphere can be labeled by clicking on the "match" icon.

Be sure to check the slice for proper labeling and, make sure to save before moving on to the next slice.

Editing Parcellation Lines

To modify the parc lines, click on the "EDIT PARC LINES" icon. To resume labeling, the "SAVE EXTR LOAD" icon must once again be hit.

Displaying Labels on Defined Parcellation Units

Click on the "SHW LBL" icon to overlay the labels on the active slice.

You will find that the menu does not always provide a complete list of parcellation units for a given slice. Or that too many units are provided. This is due to the variable anatomy of the cerebral cortex. Often, the circuitous path of a fissure results in cortex extending beyond the limits of a corresponding node. PRG and POG whose borders are comprised in part by the Central, Precentral, and Postcentral Sulci, as they traverse rostro-ventrally along the lateral surface of the brain, are examples of such a phenomenon. POG cortex, for instance, can exist on a slice anterior to the CE-SYL node (the junction of the Central Sulcus and the Sylvian Fissure). This node is meant to represent the anterior border of POG so if the Central Sulcus courses rostrally anterior to this node, the menu no longer corresponds to the anatomy. As you parcellate from the rostral to the caudal end you will find POG cortex before you are provided with its label. If you find that a label is not provided by the menu, you must find that label manually.

Manually Defining a Parcellation Unit

Click on the "list" icon in the parc box. This will cause the right-hand column of the parc box to display a preset list of parcellation units. Not all the labels can be viewed at one time. To scroll through all the units, click on the "next" icon of the parc box. When you find the proper label, click on it to define the selected parcellation unit.

In the example here, the curvature of the Central Sulcus results in POG being bordered by PRG dorsally and ventrally. In that particular coronal plane, some portion of POG is surrounded by PRG. Because there is no computational cue, the most difficult aspect of doing this parcellation, is discovering when it exists. The importance of using the cross-referential tools becomes obvious

here. The coronal slice alone gives few clues to the existence of this situation. Without thorough use of the cross-referential tools, looking at the axial and sagittal views, the portion of POG that extends forward "into" the PRG is likely to be mislabeled.

Parcellation Units

Begin at the rostral end of the brain.
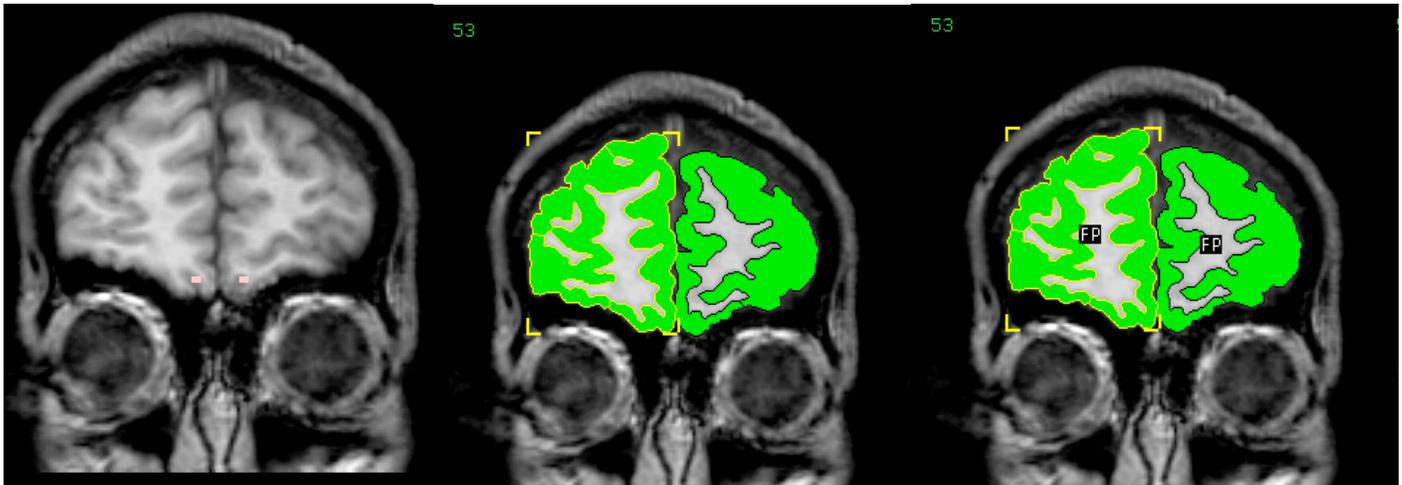
Frontal Pole

The first few slices consist solely of FP and do not require any parc lines.
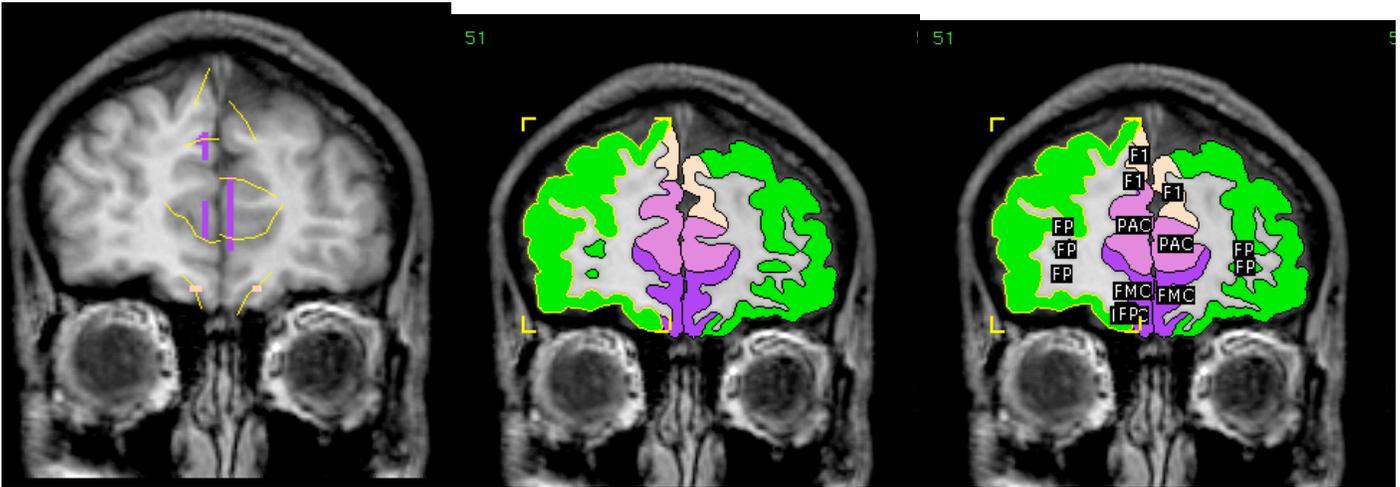
Superior Frontal Gyrus

At this level, F1 lies only on the medial surface so a parc line must be drawn at the dorsal hemispheric margin to separate F1 from FP. The parc line that divides F1 and FP is drawn obliquely from the corner of the dorsal hemispheric margin to the dorsal-medial corner of the white matter. This is usually about a 45-degree angle. The inferior border of F1 is the superior portion of the paracingulate sulcus.

Paracingulate Gyrus

Starting at the medial hemispheric margin find the superior and inferior portions of the paracingulate sulcus and trace them laterally to the white matter. The pocket of cortex between these lines you have drawn is PAC.

Keep in mind that your planes and nodes may not fall on the same coronal slice for both the left and right hemispheres. When this happens, additional units will not begin on the same slice for both hemispheres.

Make use of the alternate configuration tools to decide if cortex falls within the boundaries of a particular unit.

Frontal Medial Cortex

At this level of the brain you will need to find the olfactory sulcus along the ventral surface of the brain. The olfactory sulcus is the border between the FMC medially and FP laterally. The inferior portion of the paracingulate sulcus is the superior border of the FMC.
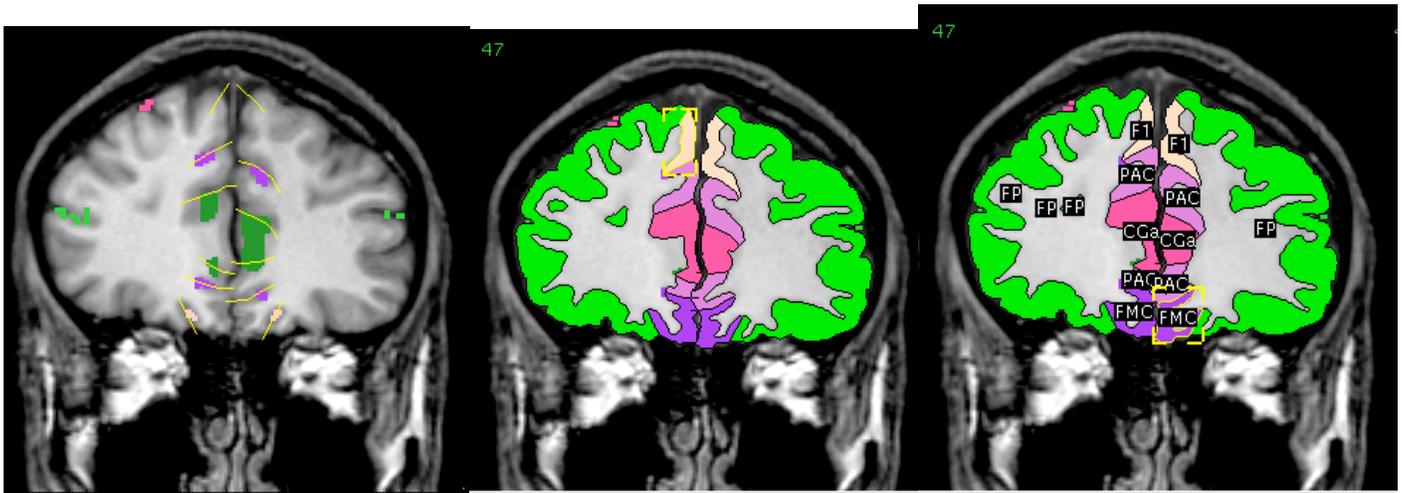
Cingulate Gyrus - Anterior Division

As you continue to move caudally, the next parcellation unit to emerge will be CGa. At its anterior-most level, CGa is bordered ventrally and dorsally by cingulate sulcus and, as such, is surrounded by PAC. At the anterior tip of CGa, be sure to label only that cortex which is caudal to the curvature of the cingulate sulcus.
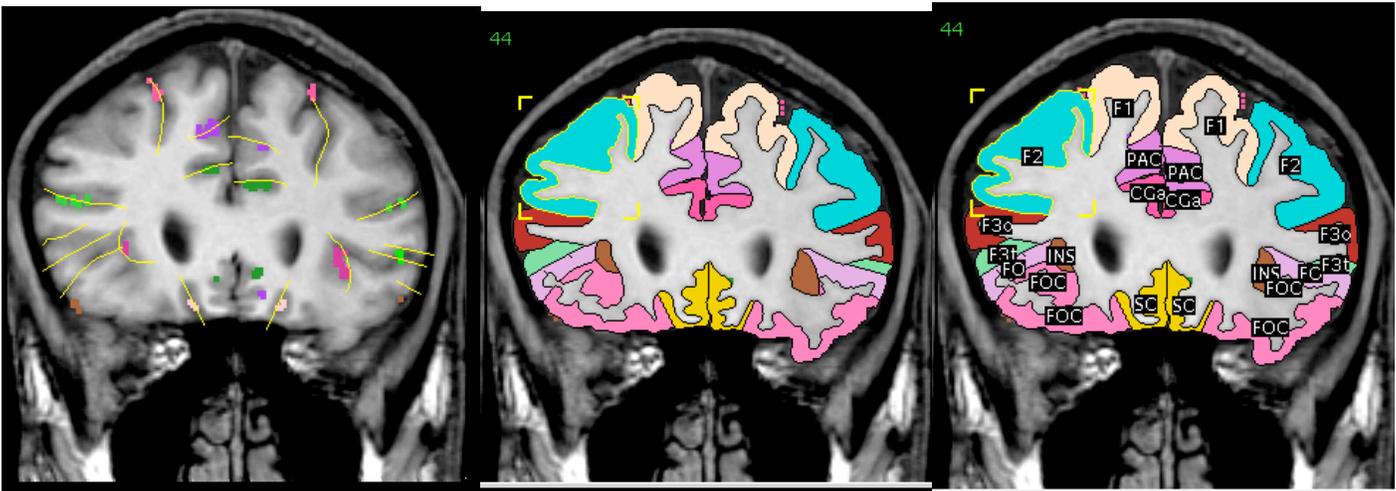
Insular Cortex

Next we see the anterior most portion of the insula. This area can be tricky to parcellate because of its orientation in the cerebrum. It does not appear to be on the external surface. Instead, it is nestled deep in the sylvian fissure, bordered by the circular sulcus of the Insula. Use the sagittal and axial views to help find these borders. Oblique sulci lines such as those used to separate F1 from FP earlier, must be drawn to demarcate the superior and inferior borders of the Insula. For the superior border, draw a sulci line from the dorsomedial-most corner of the insula to the dorsal-most portion of the Circular Sulcus of the Insula. This line should then follow the sylvian fissure to the lateral hemispheric margin. For the inferior border, draw a line for the ventromedial-most corner of the insula to the ventral-most portion of the circular sulcus of the insula, connecting it to the superior border parc line. At more caudal levels, the sylvian fissure is often drawn as part of the cerebral exterior during segmentation, thus making it easier to parcellate the insula.

Frontal Operculum

FO's anterior border is the anterior horizontal ramus of the sylvian. Its posterior border is plane O. It is bordered laterally by the hemispheric margin and medially by the circular sulcus of the insula. Plane O is the point where the precentral hits the sylvian sulcus. The parcellation lines for the frontal operculum are drawn as follows: The anterior line is drawn at a general 45 degree angle from a tip of white matter slightly above the insula to the hemispheric margin so that the insula is mostly covered by operculum. The posterior line is usually created by present white matter, however if this is not present, the parcellation line is drawn along the anterior horizontal ramus of the sylvian. Eventually the FO will change to CO as you move posteriorly through the coronal images.

Subcallosal Cortex

SC is bordered anteriorly by plane I and posteriorly by the septum. Medially it is bordered by the olfactory fissure, and laterally by the callosal fissure. Plane I is the anterior tip of the genu of the corpus callosum. One parcellation line on each hemisphere is necessary for SC. A line along the olfactory fissure will create the border for the subcallosal cortex.

Inferior Frontal Gyrus - Pars Opercularis

F3o is bordered anteriorly by the node aar-if, where the anterior ascending ramus of the sylvian hits the inferior frontal. Posteriorly it is bordered by the node if-prc, where the inferior frontal hits the precentral. Medially F3o is bordered by the inferior frontal fissure, and laterally by the anterior horizontal ramus of the sylvian or the precentral fissure. Parcellation lines should be drawn at the inferior frontal sulci. The other parcellation line should be drawn at the anterior horizontal ramus of the sylvian if F3t is still present, or at the sylvian fissure when F3t is no longer present, and lastly at the precentral when PRG becomes present posterior to the F3o.

Middle Frontal Gyrus

F2 is bordered anteriorly by plane A and posteriorly by where the superior frontal sulcus hits the precentral sulcus (sf-prc). Medially it is bordered by the superior frontal, and laterally by the intersection of the inferior frontal with the precentral (if-prc). Plane A is defined as the rostral end of the anterior horizontal ramus of the sylvian fissure. The parcellation lines should be drawn along the sulcus of the superior frontal and the inferior frontal. When more posterior coronally, the lower parcellation line should be drawn in the precentral sulcus.

Frontal Orbital Cortex

FOC is bordered anteriorly by plane A and posteriorly by the basal forebrain. Plane A is defined as the rostral end of the anterior horizontal ramus of the sylvian fissure. Medially FOC is bordered by the anterior horizontal ramus of the sylvian and laterally by the olfactory fissure. Parcellation lines should be drawn along the olfactory sulcus and along the anterior horizontal ramus of the sylvian.

Inferior Frontal Gyrus - Pars Triangularis

F3t is bordered anteriorly by plane A, and posteriorly by the anterior ascending ramus of the sylvian. Plane A is defined as the rostral end of the anterior horizontal ramus of the sylvian fissure. Medially it is bordered by the inferior frontal sulcus, and laterally by the anterior horizontal ramus of the sylvian. The parcellation lines should be drawn as follows: One should be drawn along the sulcus of the anterior horizontal ramus of the sylvian while another parcellation line should be drawn along the inferior frontal sulcus, and more posteriorly along the anterior ascending ramus of the sylvian sulcus.

Temporal Pole

TP is the most anterior part of the temporal lobe. It is anteriorly bordered by the hemispheric margin and posteriorly bordered by plane B. Plane B is the caudal border of the temporal pole before the frontal-temporal continuity. There are no parcellation lines to be drawn for the temporal pole. Eventually as you move more posteriorly through the coronal slices the temporal lobe will be split up by the superior temporal, inferior temporal, occipitotemporal, and collateral sulci. The label for the TP is found in the "Auxlab" menu.

Central Opercular Cortex

CO is one of the three frontoparietal operculum. It is defined by its anterior border, plane O, and by its posterior border, plane P. It is laterally bordered by the hemispheric margin, and medially by the circular sulcus of the insula. Plane O is defined by the inferior end of the precentral sulcus at the sylvian fissure, while plane P is defined by the inferior end of the postcentral sulcus at the sylvian fissure. The parcellation lines for the central operculum are drawn as follows: The anterior line is drawn at a general 45 degree angle from a tip of white matter slightly above the insula to the hemispheric margin so that the insula is mostly covered by operculum. In more posterior coronal slices it points towards the tip of the temporal lobe so as to create the image of "lips" along with the planum polare (PP). The posterior line is usually created by present white matter, however if this is not present, the parcellation line is drawn along the anterior horizontal ramus of the sylvian. Eventually the CO will change to PO as you move posteriorly through the coronal images.

Precentral Gyrus

PRG is bordered anteriorly by plane O and posteriorly by plane L. It is bordered medially by the node ce-sy, the intersection of the precentral and the cingulate. PRG is bordered laterally by the intersection of the sylvian fissure with the central fissure. (If neither precentral nor central fissures hit the cingulate, the most dorsal points of the two sulci are taken). Plane O is the point where the precentral hits the sylvian sulcus. Plane L is the dorsal end of the central sulcus where it meets the medial hemispheric margin. Parcellation lines should be drawn along the precentral sulcus and along the central sulcus.
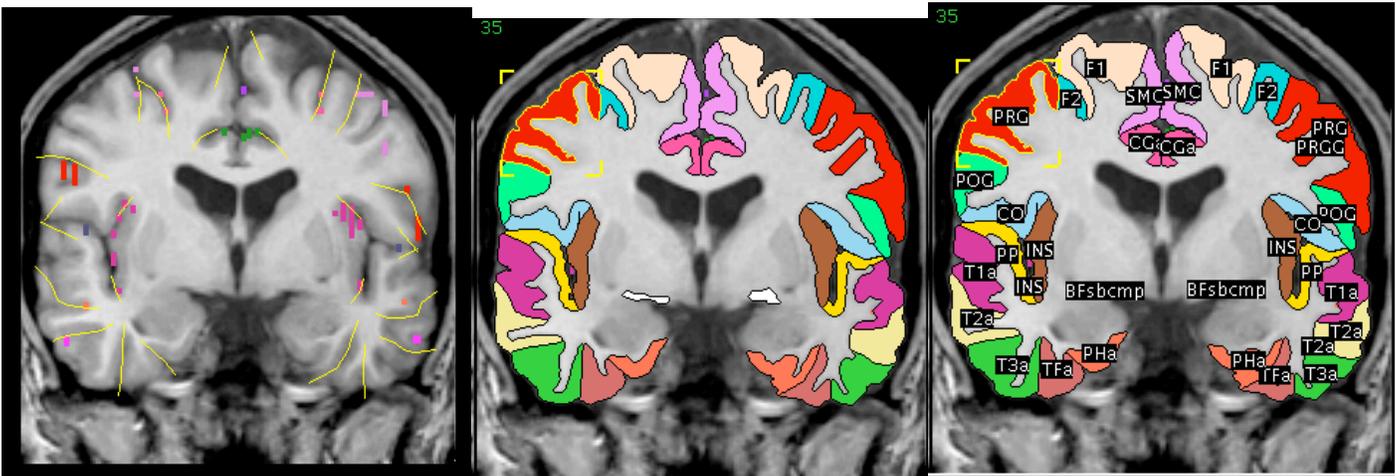
Planum Polare

PP is one of the three temporal operculum. It is defined by its anterior border plane B and by its posterior border the first transverse fissure. It is laterally bordered by the hemispheric margin and medially by the circular sulcus of the insula. Plane B is identified as the caudal border of the temporal pole. It is the coronal slice with temporal pole before the frontal-temporal continuity. The first transverse sulcus is the sulcus lying just in front of and parallel to Heschl's gyrus. The parcellation lines for the planum polare are drawn as follows: The posterior line is drawn at a 45 degree angle from the base of the insula to the hemispheric margin. (This often creates the image of "lips" along with the operculum above). The anterior border is usually white matter, however can be drawn in if necessary where the anterior ascending ramus of the sylvian sulci are present. In more posterior slices the PP will eventually disappear leaving H1 and PT as the temporal operculum. In the cases when all three are present the line for the planum polare border is drawn along the first transverse fissure.

Superior Temporal Gyrus - Anterior Division

T1a is bordered anteriorly by plane B, posteriorly by plane C, ventrally by the superior temporal sulci, and is bordered dorsally by the posterior horizontal ramus of the sylvian. Plane B is identified as the caudal border of the temporal pole. (The isthmus of temporal and frontal lobes). It is the coronal slice with temporal pole before the frontal-temporal continuity. Plane C is the most rostral level of the Heschl's gyrus. In each slice where T1a will be drawn in, it is bordered medially by the hemispheric margin. The parcellation lines are drawn as follows: The anterior line should be formed from the bottom of the sulcus drawn for the planum polare (PP). Otherwise, a 45 degree angled line from the base of the white matter under the insula to the hemispheric margin. Posteriorly, the parcellation line should be drawn along the sulci of the superior temporal sulcus.

Middle Temporal Gyrus - Anterior Division

T2a is defined anteriorly by plane B and posteriorly by plane C. Ventrally it is bordered by the inferior temporal fissure, and dorsally by the superior temporal fissure. Plane B is identified as the coronal slice with temporal pole before the frontal-temporal continuity. Plane C is the most rostral level of the Heschl's gyrus. T2a is drawn with two parcellation lines. One that follows the sulci of the superior temporal sulci and a posterior line drawn along the inferior temporal sulci. T2a also extends to the hemispheric margin.

Inferior Temporal Gyrus - Anterior Division

T3a is bordered anteriorly by plane B, and posteriorly by plane C. Plane B is identified as the coronal slice with temporal pole before the frontal-temporal continuity. Plane C is the most rostral level of the Heschl's gyrus. Medially T3a is bordered by the inferior temporal fissure, and laterally is bordered by the occipitotemporal sulci. T3a also extends to the hemispheric margin. To draw T3a, one parcellation line must be drawn in the fissure of the temporal pole, where sulci will be visible, and another parcellation line must be drawn along the sulcus of the occipitotemporal fissure.

Temporal Frontal Cortex - Anterior Division

TFa is part of the temporal and occipital lobes. It is bordered anteriorly by plane B and posteriorly by plane C. Laterally TFa is bordered by the occipitotemporal sulcus and medially by the collateral sulcus. Plane B is identified as the coronal slice with temporal pole before the frontal-temporal continuity. Plane C is the most rostral level of the Heschl's gyrus. The parcellation lines for TFa are drawn as follows: One parcellation line is drawn along the sulci of the occipitotemporal sulcus. Another parcellation line is drawn along the sulci of the collateral sulcus. TFa extends to the hemispheric margin.

Parahippocampal Gyrus - Anterior Division

PHa is anteriorly bordered by plane B. Its posterior border is plane M. Laterally it is bordered by the collateral sulcus and medially it is bordered by the hippocampal fissure. Plane B is identified as the coronal slice with temporal pole before the frontal-temporal continuity. Plane M is the most rostral coronal slice containing full thickness of the lateral geniculate nucleus (LGN). To draw the parcellation lines for PHa, one line must be drawn along the sulci of the collateral sulcus. Another line must be drawn in the hippocampal fissure horizontally to the hemispheric margin.

Postcentral Gyrus

POG is bordered anteriorly by the node ce-sy, where the central fissure hits the sylvian, or the most dorsal portion of the central fissure. Posteriorly it is bordered by the node poc-HM, where the postcentral fissure hits the hemispheric margin. POG is bordered medially by the node ce-ci. where the central fissure hits the cingulate fissure. Laterally POG is bordered by the node sy-poc, where the sylvian hits the postcentral fissure, or the most dorsal part of the postcentral sulcus. The parcellation lines should be drawn along the postcentral sulcus and the central sulcus.

Juxtapositional Lobule Cortex
(Supplementary Motor Cortex)

JPL (SMC) is anteriorly bordered by plane J and posteriorly bordered by plane K. Plane J is defined by the anterior commissure and is automatically given to you by the program. Plane K is the dorsal end of the precentral sulcus where the precentral sulcus meets the medial hemispheric margin. Medially it is bordered by the cingulate fissure. Laterally it is bordered by the interhemispheric fissure and eventually the hemispheric margin. A 45 degree angled straight parcellation line is drawn from the largest tip of white matter towards the medial hemispheric margin. Another parcellation line is drawn along the cingulate fissure.

Basal Forebrain

BFsbcmp is the orbitofrontal cortex posterior limit. This unit appears once posterior to the subcallosal cortex (SC). The BFsbcmp label is found in the "Auxlab" menu.
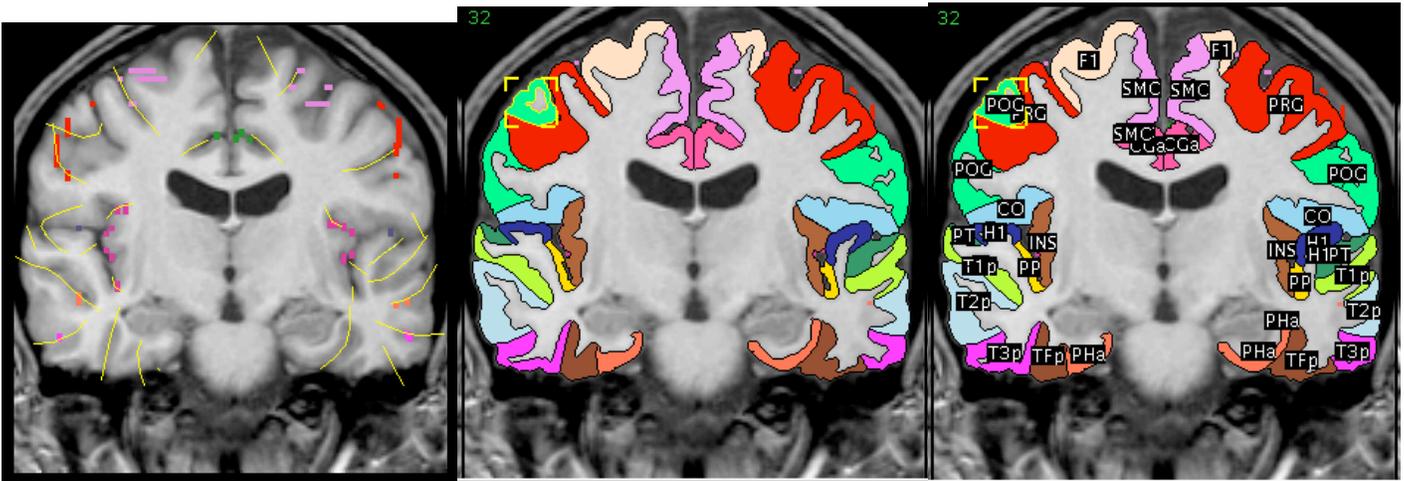
Inferior Temporal Gyrus - Posterior Division

T3p is defined laterally by the inferior temporal sulcus (it) and medially by the occipital temporal sulcus (ot). T3p is defined anteriorly by plane C (the most rostral level of Heschl's gyrus) and posteriorly at plane D (the end-point of the sylvian fissure).

Temporal Frontal Cortex - Posterior Division

TFp is defined laterally by the occipital temporal sulcus (ot) and medially by the collateral sulcus (co). TFp is defined anteriorly by plane C (the most rostral level of Heschl's gyrus) and posteriorly at plane D (the end-point of the sylvian fissure).

Heschl's Gyrus

H1 is bordered anteriorly by the first transverse fissure, and posteriorly it is bordered by Heschl's fissure. Laterally H1 is bordered by the hemispheric margin and medially by the circular sulcus of the insula. To draw the parcellation lines, draw one line at a 45 degree angle along where the Heschl's sulcus was drawn on the lateral side of the "thumb" of white matter near the insula. Another line is drawn at a 45 degree angle along where the first transverse sulcus was drawn on the medial side of the "thumb" of white matter. Eventually as you move posterior through the coronal slices the H1 will disappear leaving only PT.

Planum Temporale

PT is one of the three temporal operculum. PT is bordered anteriorly by the heschl's gyrus. It is bordered posteriorly by plane D. Medially, PT is bordered anteriorly by heschl's gyrus, and as you move posteriorly in the coronal views, it is bordered by the circular sulcus of insula and eventually the sylvian fissure. Laterally PT is bordered by the sylvian fissure at the hemispheric margin. Plane D is the anterior border of the temporoparietal transition zone on the lateral brain surface and of the occipitotemporal transition zone on the lateral and ventral brain surfaces. The parcellation lines for PT are drawn as follows: One line is drawn at a 45 degree angle along the Heschl's gyrus. Another line is drawn at a 45 degree angle from the tip of white matter in the upper temporal lobe to the hemispheric margin. When PT is the only temporal operculum left, only the parcellation line at the hemispheric margin is needed, as the bottom of the insula will form the border for the other parcellation line.

Superior Temporal Gyrus - Posterior Division

T1p is bordered anteriorly by plane C, and posteriorly by plane D. Medially it is bordered by the sylvian fissure at the hemispheric margin. Laterally T1p is bordered by the superior temporal fissure. Plane C is the most rostral level of the Heschl's gyrus. Plane D is the anterior border of the temporoparietal transition zone on the lateral brain surface and of the occipitotemporal transition zone on the lateral and ventral brain surfaces. A parcellation line must be drawn along the sylvian fissure and another along the superior temporal fissure.

Middle Temporal Gyrus - Posterior Division

T2p is bordered anteriorly by plane C, and posteriorly by plane D. Medially it is bordered by the superior temporal fissure, and laterally T2p is bordered by the inferior temporal fissure. Plane C is the most rostral level of the Heschl's gyrus. Plane D is the anterior border of the temporoparietal transition zone on the lateral brain surface and of the occipitotemporal transition zone on the lateral and ventral brain surfaces. One parcellation line must be drawn along the sulci of the superior temporal fissure, and another line must be drawn along the sulci of the inferior temporal fissure.
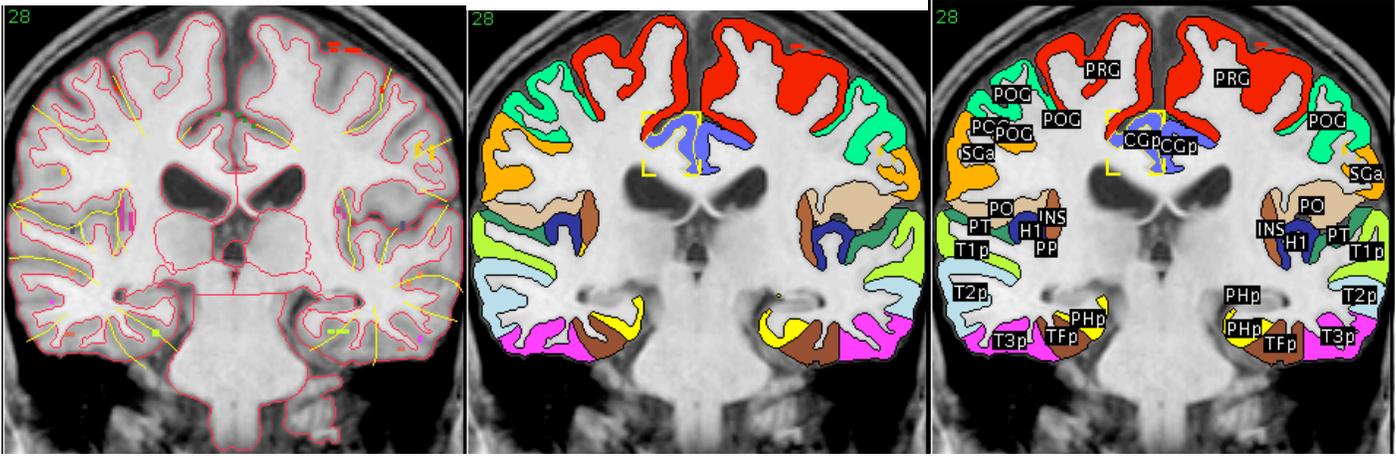
Cingulate Gyrus - Posterior Division

CGp is defined inferiorly in its more anterior extent by the callosal sulcus (ca) or the corpus callosum. The superior border in the more anterior extent is the cingulate sulcus (ci). In the medial extent, the CGp curves under the corpus callosum (sagittal view). The inferior border in medial extent of the CGp above the corpus callosum is the corpus callosum (ca). The inferior border for the portion under the corpus callosum is the calcarine sulcus (calc). The superior border in the medial extent for the portion above the corpus callosum is the cingulate sulcus (ci). The superior border for the medial portion of the CGp under the corpus callosum is the corpus callosum (ca). After the splenium node (SPLN, the most caudal corpus callosum connection), the CGp will cease to be split by the corpus callosum. At this point the calcarine sulcus (calc) is the inferior border and the subparietal sulcus (sp) is the superior border. The anterior border for the portion above the corpus callosum is Plane K (the dorsal end of precentral sulcus). The anterior border for the portion under the corpus callosum is Plane N (the rostral tip of the calcarine sulcus). The posterior border for the superior portion is the node at the junction of the subparietal sulcus and the cingulate sulcus (sp-ci). The node at the junction of the subparietal sulcus and the calcarine sulcus (sp-calc) is the posterior border for the more inferior part. The posterior border is basically defined by the subparietal sulcus (sp).

Supramarginal Gyrus - Anterior Division

SGa is defined inferiorly by the Sylvian sulcus (sy) more specific, the posterior horizontal ramus of the Sylvian fissure (phr) and the posterior ascending ramus of the Sylvian fissure (par). The superior border is the postcentral sulcus (poc), until it changes after the node at the junction of the postcentral sulcus (poc) and the intraparietal sulcus (ip) to the intraparietal sulcus. The anterior border is officially plane P (where the postcentral sulcus meets the Sylvian fissure) but this border must follow the postcentral sulcus (poc), therefore if the postcentral sulcus leans posterior after plane P then the anterior border of SGa will be more posterior to plane P. The posterior border is plane D (the end-point of the Sylvian fissure).

Parietal Operculum

PO is defined laterally by a 45 degree angle drawn to the hemispheric margin. The medial border is defined by the circular sulcus of the insula (cir). The anterior border is plane P (the point where the postcentral sulcus meets the Sylvian sulcus). The posterior border is plane D (the end-point of the Sylvian fissure).

Parahippocampal Gyrus - Posterior Division

PHp is defined laterally by the collateral sulcus (co), and medially by the hippocampus (as outlined by prior segmentation). The anterior border is defined by plane M (the most rostral coronal slice containing full thickness of the lateral geniculate nucleus). The posterior border is plane N(the rostral tip of the calcarine sulcus).
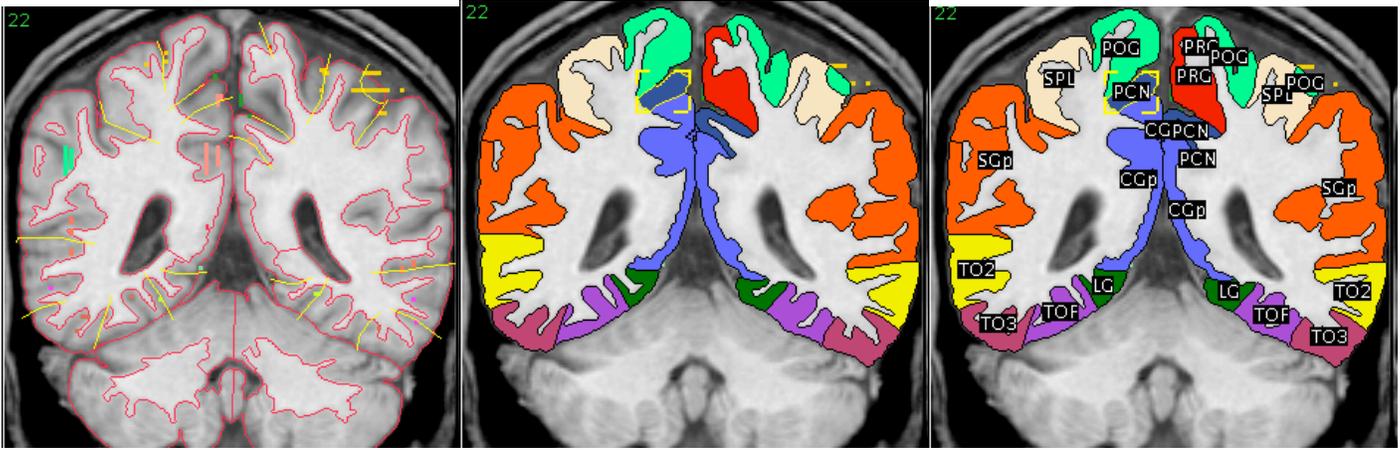
Precuneous Cortex

PCN is defined inferiorly by the subparietal sulcus (sp) in the anterior portion, the calcarine (calc) sulcus in the middle portion, and by the parietal occipital (po) in the most posterior portion. The superior border is the cingulate sulcus (ci) in the most anterior portion and then changes to the hemispheric (as defined by a 45 degree angle) once the cingulate has curved up to the hemispheric margin. The anterior border is the node at the junction of the subparietal sulcus and the cingulate sulcus (sp-ci). The anterior border follows the subparietal sulcus (sp), therefore anything in front of the subparietal sulcus is not PCN, even if it is posterior the sp-ci node. The posterior border is the node at the junction of the parietal occipital sulcus (po) and the hemispheric margin (po-HM). This border follows the parietal occipital sulcus so anything after the sulcus is not PCN even if it is anterior to the node.

Superior Parietal Lobule

SPL is defined inferiorly by the intraparietal sulcus (ip), and superiorly by the hemispheric margin (defined as a 45 degree angle). The anterior border is the node at the junction of the postcentral sulcus and intraparietal sulcus (poc-ip). The anterior border follows the postcentral sulcus (poc). The posterior border is plane F (the point where the intraparietal sulcus opercularizes).

Supramarginal Gyrus - Posterior Division

SGp is defined inferiorly by the superior temporal sulcus (st) and superiorly by the intraparietal sulcus (ip). The anterior border is defined by plane D (the end-point of the Sylvian sulcus). The posterior border is plane E (the inferior end of the intermediate sulcus of Jensen).

Middle Temporal Gyrus - Temporooccipital Part

TO2 is defined medially (or inferiorly) by the inferior temporal sulcus (it) and laterally (or superiorly) by the superior temporal sulcus (st). The anterior border is defined by plane D (the end-point of the Sylvian fissure), and the posterior border is plane F (the point where the intraparietal sulcus opercularizes).

Inferior Temporal Gyrus - Temporooccipital Part

TO3, the inferior temporal gyrus/temporooccipital part, is defined medially by the occipital temporal sulcus (ot) and laterally by the inferior temporal sulcus (it). The anterior border is plane D (the end-point of the Sylvian fissure) and the posterior border is plane F (the point where the intraparietal sulcus opercularizes).

Temporal Occipital Fusiform Cortex

TOF is defined medially by the collateral sulcus (co), and laterally by the occipital temporal sulcus (ot). The anterior border is defined by plane D (the end-point of the Sylvian sulcus) and the posterior border is defined by plane F (the point where the intraparietal sulcus opercularizes).

Lingual Gyrus

LG is defined medially by the calcarine sulcus (calc), and laterally by the collateral sulcus (co). The anterior border is plane N (the rostral tip of the calcarine sulcus), and the posterior border is defined by plane G (the caudal tip of the cuneal sulcus).
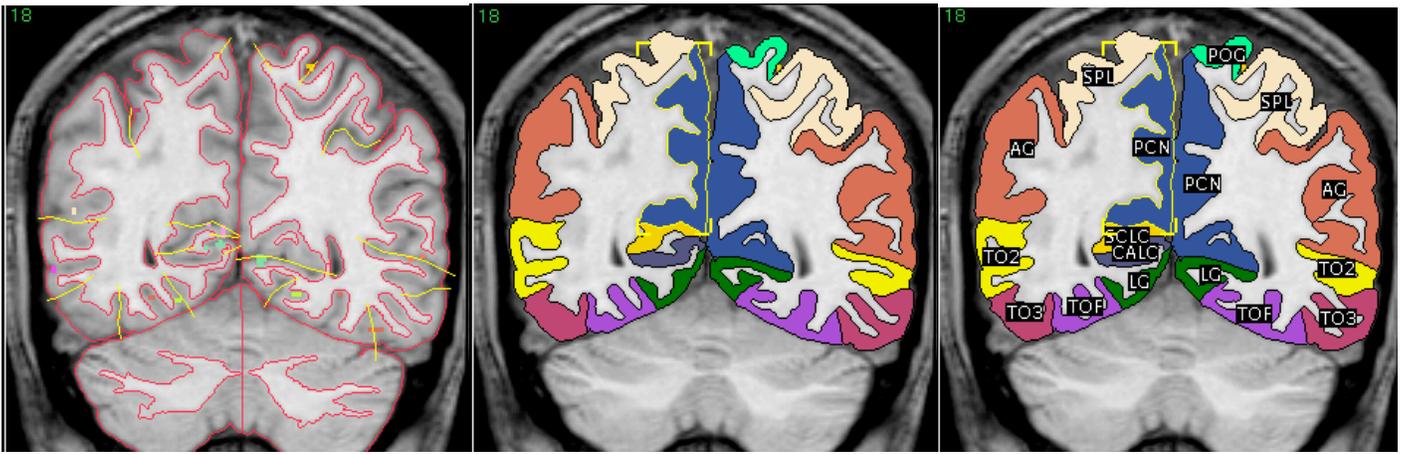
Angular Gyrus

AG is defined inferiorly by the lateral occipital sulcus (lo) and superiorly by the intraparietal sulcus (ip). The anterior border follows the intermediate sulcus of Jensen (ij) and is defined by plane E (the inferior end of the intermediate sulcus of Jensen) as well as the node at the junction of the intermediate sulcus of Jensen's and the intraparietal sulcus (ij-ip). The posterior border is plane F (the point where the intraparietal sulcus opercularizes).

Intracalcarine Cortex

CALC is the only parcellation unit where "parc" lines are drawn around a sulcus. Therefore the inferior border is the inferior border of the calcarine sulcus (calc) and the superior border is the superior border of the calcarine sulcus (calc). The anterior border is the cuneal point (CUNPNT, where the calcarine sulcus and parietal occipital sulcus meet). The posterior border is plane G (the caudal tip of the cuneal sulcus).

Supracalcarine Cortex

SCLC is defined inferiorly by the superior border of the calcarine sulcus (calc). The superior border is the parietal occipital sulcus (po) until the cuneal sulcus (cun) appears. The cuneal sulcus (cun) then becomes the superior border. The anterior border is the cuneal point (CUNPNT, where the calcarine sulcus and parietal occipital sulcus meet). The posterior border is plane G (the caudal tip of the cuneal sulcus).
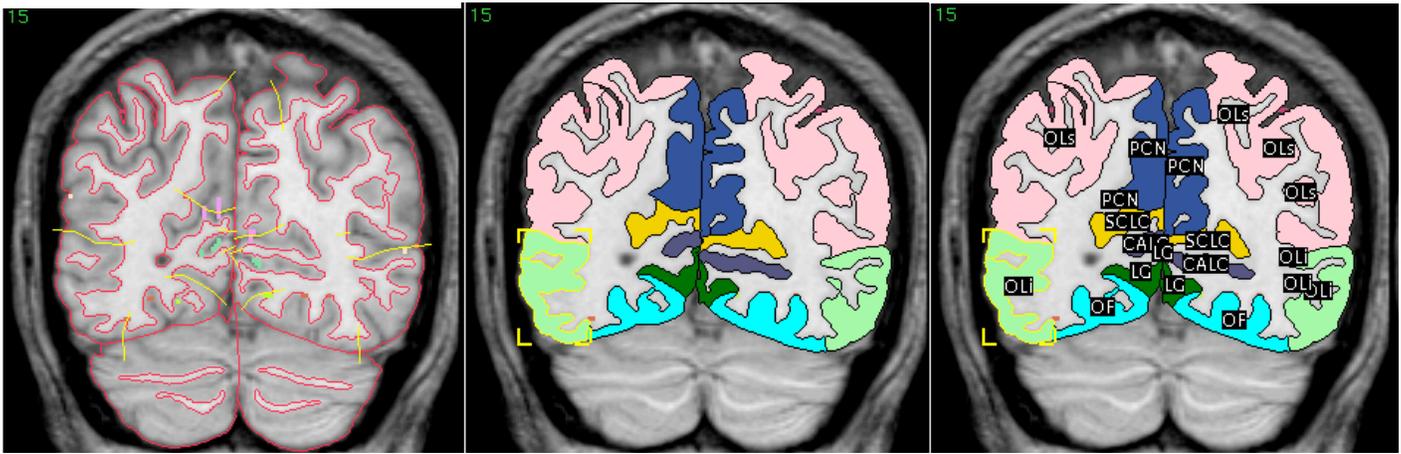
Lateral Occipital Cortex - Superior Division

OLs is defined inferiorly by the lateral occipital sulcus (lo), and superiorly by the hemispheric (defined by a 45 degree angle). The anterior border is plane F (the point where the intraparietal sulcus opercularizes) and the posterior border is plane G (the caudal tip of the cuneal sulcus).

Lateral Occipital Cortex - Inferior Division

OLi is defined inferiorly by the occipital temporal sulcus (ot) and superiorly by the lateral occipital sulcus (lo). The anterior border is plane F (the point where the intraparietal sulcus opercularizes) and the posterior border is plane G (the caudal tip of the cuneal sulcus).

Occipital Fusiform Gyrus

OF is defined medially by the collateral sulcus (co), and laterally by the occipital temporal sulcus (ot). The anterior border is plane F (the point where the intraparietal sulcus opercularizes) and the posterior border is plane G (the caudal tip of the cuneal sulcus).
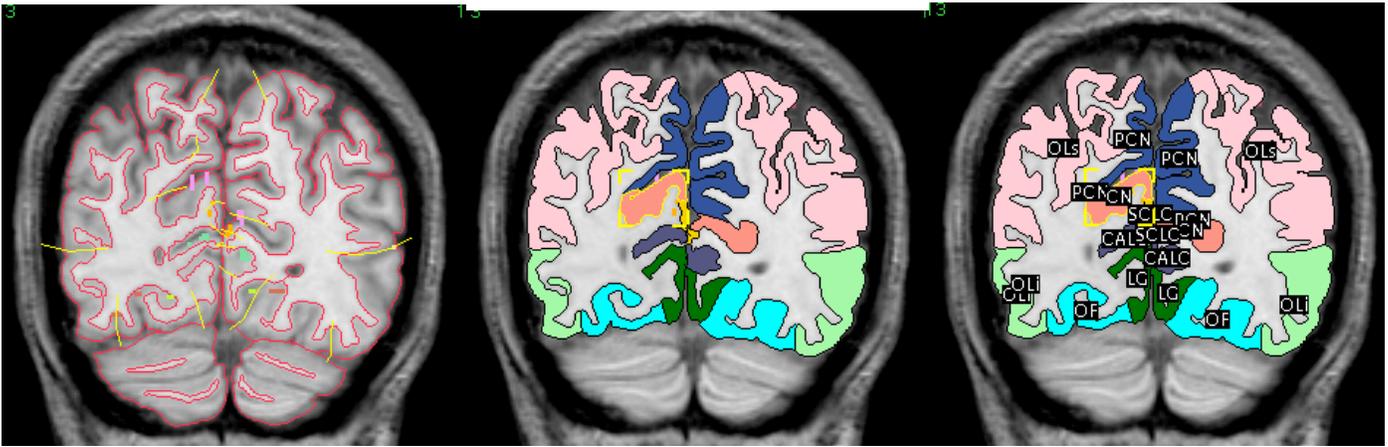
Cuneal Cortex

CN is defined inferiorly by the cuneal sulcus (cun) and superiorly by the parietal occipital sulcus (po) until it meets the hemispheric margin where the hemispheric margin (defined by a 45 degree angle) then defines the superior border. The anterior border is defined by the node at the junction of the cuneal sulcus and the parietal occipital sulcus (cun-po), but the border follows the parietal occipital sulcus (po). The posterior border is plane G (the caudal tip of the cuneal sulcus).
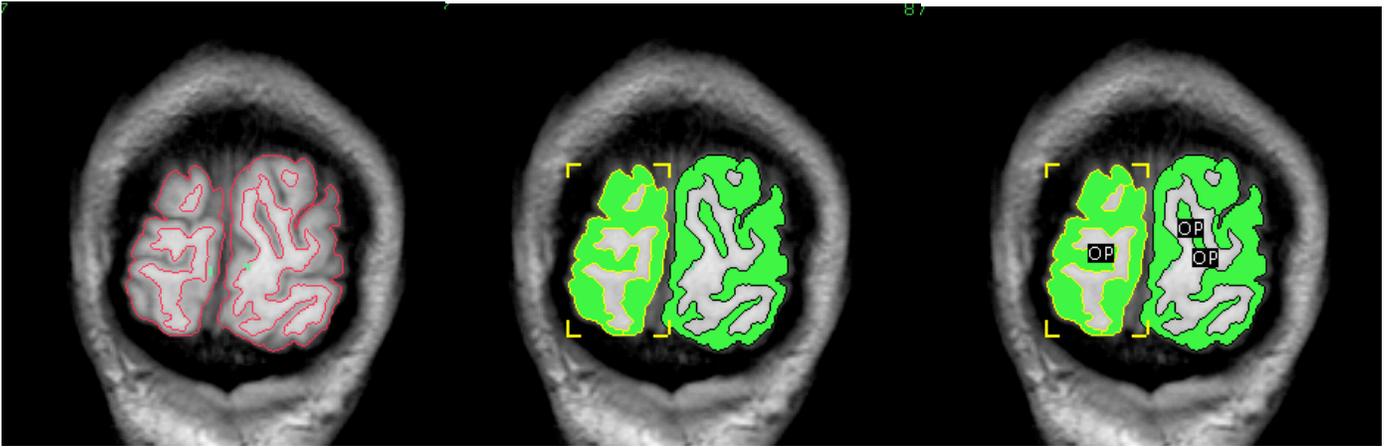
Occipital Pole

OP is the most posterior extent of the occipital lobe. Its anterior border is plane G. Posteriorly it is bordered by the hemispheric margin. Also, both ventrally and dorsally it is bordered by the hemispheric margin. Plane G is the caudal tip of the cuneal sulcus where there is still visible full thickness cortex. No parcellation lines are needed to label the occipital pole.

White Matter Parcellation

White matter parcellation is a semi-automated process that defines all of the white matter parcellation units by running a Unix-based program. In order for the white matter parcellation to be processed properly, both segmentation and cortical parcellation of the brain must be completed correctly. Any flaws in segmentation or cortical parcellation will result in errors in white matter parcellation. If the resultant white matter parcellation you observe is incorrect, go back and check your segmentation and cortical parcellation for any errors, then run the white matter parcellation program again.

Procedure
-complete segmentation and cortical parcellation of the brain; be sure to correct any mistakes

-run the following program from a Unix-based computer:
    /cmas/abyss56/bins/jim/solaris/wm_extr <PID> <scan #> <"I" file> <"sulci/node" prefix> <"J" file> BXX <<"seg" prefix>WW> -1 60

> "I" file (capital "i") is segmentation prefix with "I" (e.g. abcI)
> "sulci/node" file is segmentation prefix with "s" (e.g. abcs)
> "J" file is "sulci/node" prefix with "J" (e.g. abcsJ)
> "seg" prefix is the segmentor's/parcellator's initials (e.g. Andrew Byron Cummings' "seg" prefix is abc)

> ***The notes on prefixes above conform to current CMA naming conventions. If you are analyzing data segmented/parcellated before the current conventions were implemented, your prefixes may be of a different format.***

> use –1 120 for 120 slice brain.

> ***If you are not at the CMA the location of the program may differ, but the syntax will be the same.***

Viewing white matter parcellation
-start CardViews normally

-to check the setup for white matter parcellation:
    load prefix BXX in Seg mode

-to view deep white matter:
    load prefix <"seg" prefix>WW
    load "wm_parc.otl_label" label file in Rev mode

-to view superficial white matter:
    load prefix <"seg" prefix>WW
    load "cort_parc.otl_label" label file in Rev mode

Remember: if the resultant white matter parcellation you observe is incorrect, go back and check your segmentation and cortical parcellation for any errors, then run the white matter parcellation program again!

Generating Volumetric Data with XVol

XVol is a tool used for volumetric analysis of the brain. After you have segmented and/or parcellated the brain, you use XVol to determine the volumes of all the structures you have identified and also to establish a comparison between different brains and between different rators' results of the same brain.

Running XVol for Volumetry
-At your home prompt, type xvol. Hit return.

-Click on "START." A bigger screen will appear.

-On the right of this bigger screen, click on "CMA Basic", this will unselect the "Don't Sort" box.

-Under the "Set OTL Path", put your cursor in the "PID" box and type in the number of the brain you are checking (this is the patient identification number). You will have to hit return in order for this box to accept the number you typed in. Now type in the scan number of the brain you are checking in the "SCN" box and hit return. Lastly, type in your segmentation or parcellation initials in the "PRE" box and hit return. Example: 7, 45, bmg

-Click on the "*" button, this will check which slices you have segmented/parcellated and will automatically insert the range you want.

-Once the range is displayed, click on "from info file"; this will load the voxel dimensions. A small screen will appear, click on the "Load" button, this will load your outlines.

-Now go to the top of the screen and click on the "CONTINUE" button. A new screen will appear.

-Click "graph" under the heading "File: Simple Volume".

-Click on "Continue" again. Another new screen will appear.

-Now click on "Run Volumes". This may take a few minutes. This may take a few minutes, but when it is finished running, any errors will be marked with red check marks like in the simple volume analysis. These errors must be corrected before you can continue. Once corrected, run the comparison from the beginning.

-The data you want to look at will be in a series of four columns. You will need to click on "View Data" and then next to the checked box, click on either "view" or "print". The names of the structures are listed on the far left and the volumes on the right.

Running a volumetric comparison with XVol
-Now you are ready to examine the differences between measurements of different rators of the same brain structures to establish inter-rator reliability.

-Open XVol like you did in the simple volume analysis, by typing "xvol" at you home prompt. Click on "Start".

-Click on "CMA Basic".

-Click on "Comparison."

-Enter your PID, scan and prefix. Below your numbers, enter the PID, scan and prefix of the person you want to run the comparison with.

-Click on "*", then click on "from info file" and "load", just like you did previously.

       -If you need to run multiple comparisons at once, click on "add."

       -Enter PID, scan, and prefix of the next person in box #2

       -Click on "*", then click on "from info file" and "load", just like you did previously.

       -Repeat this process for each person you need to compare to.

-Click on "Continue".

-Under the heading "Set Output" click on "comp_same_ez"

-Click "Run" or "Continue", and then click on "Run Volumes". This may take a few minutes, but when it is finished running, any errors will be marked with red check marks like in the simple volume analysis. These errors must be corrected before you can continue. Once corrected, run the comparison from the beginning.

-The data you want to look at will be in a series of four columns. You will need to click on "View Data" and then next to the checked box, click on either "view" or "print". The names of the structures are listed on the far left and the column that you should look at is the far right which represents the percent of overlap between the two sets of data you are comparing.

Creating 3D Models with SegSurf

SegSurf converts CardViews segmentation and/or parcellation files into a format that can be processed and then visualized as a three-dimensional volume. SegSurf must be run on a Linux-based computer running a 24-bit Xserver. The brain to be visualized must be segmented and/or parcellated in CardViews first.

-At a terminal command prompt type: segsurf. Hit return.

-The SegSurf graphical user interface will open.
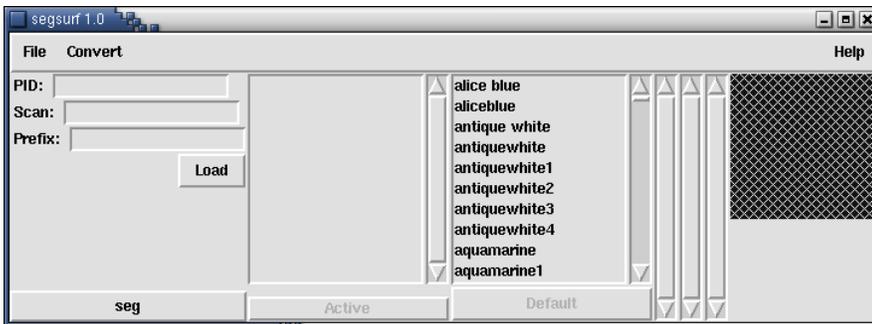
In the fields on the left side of the interface, enter the PID, and scan number of the brain you are working with as well as the prefix of the segmentation or parcellation files.

-Click the "seg" button on the bottom left of the interface to open a menu containing segmentation/parcellation label menu files. Select the appropriate label menu file for your segmentation or parcellation.

-In the list above the "Active" button, select a structure to be modeled, and then click the "Active" button. The "Active" button will turn fuchsia and the default color of the modeled structure appears on the far right of the interface. You may select another color from the list above the "Default" button. The new color of the modeled structure replaces the default color. To return to the default color of the structure click "Default". Repeat the above steps for as many structures as you wish to be modeled. To remove a structure you have already selected for modeling, select the structure in the menu and click on "Active". The "Active" button will turn gray.
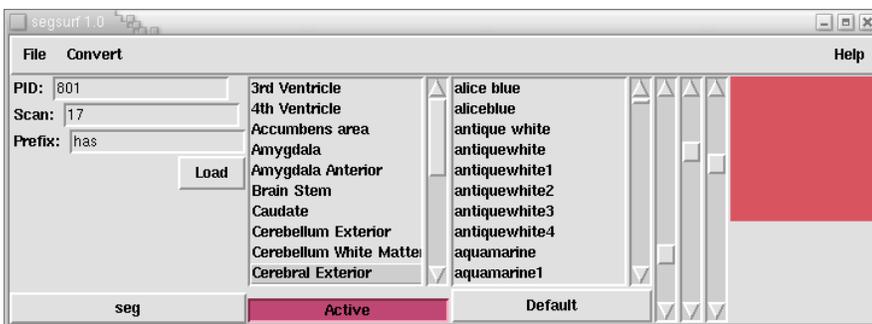
-Now the CardViews-based data must be set up to be converted to the proper format for 3D modeling. Click on "Convert" in the menu bar and select "Convert…" Another window will appear

with a list of the structures you have selected for modeling, as well as their color values (RGB). If you would like to change the list click "Close" and repeat the steps in the paragraph above.
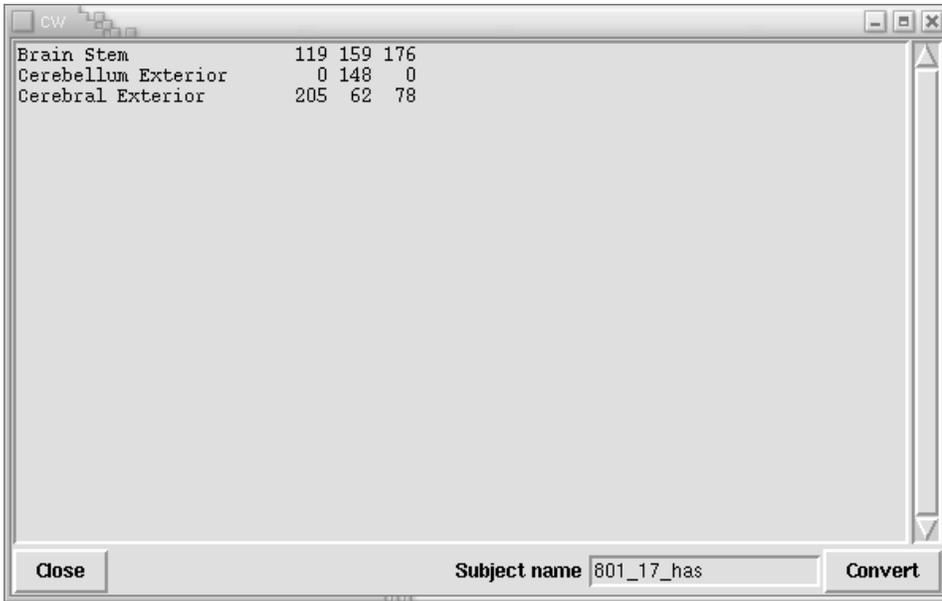
-In the "Subject name" field, enter the desired subject identifier (we suggest using the PID_SCN_prefix format). Click "Convert" to begin the conversion process. A dialogue box will appear asking if you would like to create the patient identifier you have entered; select "Yes" to continue or "No" to go back and enter a new subject identifier (the program will caution you if the subject identifier already exists). After selecting "Yes" the conversion setup process will automatically run; this will take an *extremely* short amount of time. Click "Close" in the conversion window, and then select "File" and "Quit" from the main interface.

-At the terminal command prompt type: segsurf_convert <subject identifier>. Hit return.

-The conversion process will take some time.

-When the process has completed you will be returned to the terminal command prompt.

-To view your modeled structures type: tksurfer -<subject identifier> lh smoothwm. Hit return.

-Two windows will open, one containing your modeled structures in black and white, and another containing options for viewing the data.
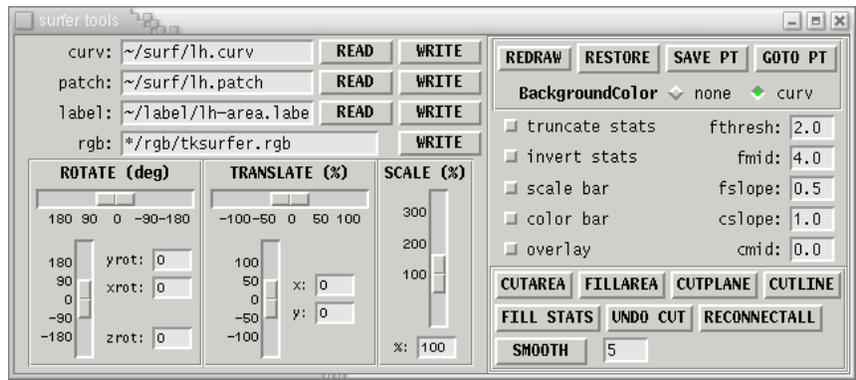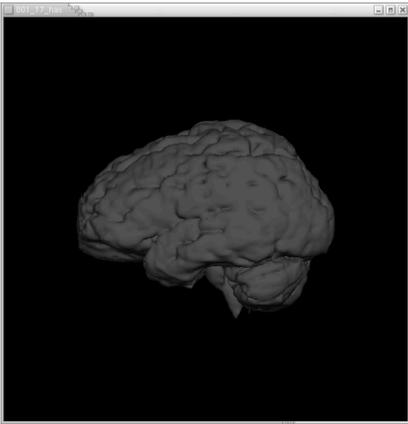
-To paint the colors onto your models, return to your terminal window and find the "%" prompt.

-Type: read_annotations segsurf.annot. Hit return.

-The window containing your modeled structures should now have appropriate colors.
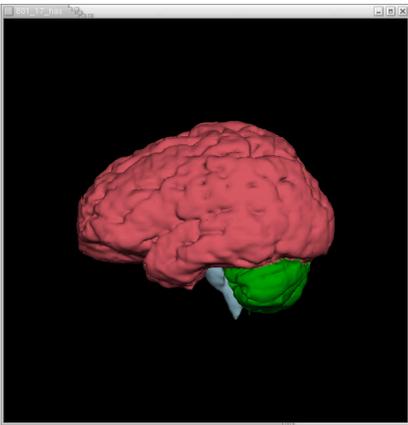
-You can use the slider-bars in the "ROTATE", "TRANSLATE", and "SCALE" sections to change the viewing angle, on-screen position, and zoom level respectively. Once you have adjusted the sliders, click "REDRAW" to apply your changes.

General Functions Summary

This summary presents the important buttons in CardViews from right to left.

Default Screen

Quit	quits CardViews
autotrans	all views will transform according to projection lines, as well as slice position in other views
NAV	go to CardViews NAV mode
SEG	go to CardViews SEG mode
REV	go to CardViews REV mode
tile display	go to CardViews tile display, where you can see many images at the same time
Projection	turns the projection lines on or off
COR	gives slice number of coronal image
SAG	gives slice number of sagittal image
AXI	gives slice number of axial image
COR, SAG, AXI arrows	allows you to change the corresponding slice
Transform	changes the slice to the number next to the corresponding position

NAV mode

SULCI FILE	gives path of where sulci files are saved
Prefix	enter the prefix to direct naming of sulci files
LOAD Sulci	loads the sulci for the given prefix
SAVE Sulci	saves sulci for the given prefix
DELETE Sulci	deletes all sulci for the given prefix
CROP Data	starts the cropping program

SEG mode

OVERLAY	indicates where the otl files are saved
Prefix	enter prefix to direct naming of otl files
-	allows you to move posteriorly though the brain
+	allows you to move anteriorly through the brain
SAVE	saves otls for a current slice
load	loads otls for current slice
drw sulc	draws sulci lines for current slice
ACl	automatically clears otls from the former slice when changing to a new slice
ALd	automatically loads otls from the new slice when changing from a previous slice
clear	clears the slice of all otls and contours
recall	loads the version of otls that have been extracted; use this to recall otls when you forget to save otls before moving to a slice

REV mode

- (top of box)	moves the brain posteriorly
+ (top of box)	moves the brain anteriorly
structures	shows the labeled structures in cartoon form
right/left	shows which structures are labeled as right/left in cartoon form
image	displays just the MRI image
outlines	displays the outlines; this mode is used when labeling
Current	displays only the current otl to be labeled
+ (middle of box)	advances to the next otl
_ (middle of box)	advances to the previous otl
delete outline	deletes the otl
r/l switch	changes the labeling of an otl from right to left, or vice versa
label menu	calls up the label menu
change menu	click on the down arrow with the third mouse button to change the label menu

Tile Display

numbers	slice numbers of the first and last images on the screen
scroll bars	used to change the slice numbers that will be seem
box next to cor	if checked, visualizes the coronal images
slice number	reads the middle slice number that is visible
up and down arrows	allows you to change slices on the top incrementally
box next to sag	if checked, visualizes the sagittal image; slice number and arrows used the same as with cor
box next to axi	if checked, visualizes the axial image; slice number and arrows used the same as with cor
prefix	enter your prefix to visualize the otls
box next to zoom	if checked, zooms the images to actual size
GO	transforms the images
CARDVWS	returns the program to the CardViews screen
down arrow next to OTL	hold with the third button to indicate the color the otls should be for the given prefix; enables you to enter up to 5 prefixes/otls at once for comparison purposes
RL	if the otls are loaded, and the brain has been labeled, color-codes what is labeled right and left
COLOR FILL	if otls are loaded, and the brain has been labeled, color-codes what is labeled right and left
arrow next to SULCI	recalls previously drawn sulci lines
arrow next to Change label	when clicked with the right mouse button changes the type of labeling menu, e.g. from cortical parcellation to white matter parcellation labels
arrow next to OSM	click either up or down to increase or decrease the number of save and recall slots
Save	saves the current screen of images, with otls, and sulci if present
RCL	recalls the saved screen (slice numbers and orientation are given on the line to the left)
toggle	allows you to switch back and forth between r/l colorfill and otls.
box next to line	if checked shows previously drawn parc lines
box next to label	if checked pulls up parcellation label menu and pulls up previous labeling
create	Hit this button and right click in desired area on images and a green cross-hair will appear. This works only if the "mark" button is selected
destroy	gets rid of the crosshair
activate	turns the green crosshair red and freezes it, this allows you to create another cross-hair while the red one stays in place
deactivate	turns the red crosshair back to green and allows you to move the green cross-hair around again
cor, sag, and ax buttons	pulls up the slice number next to the orientation in CardViews
color review	recalls extracted outlines if prefix is entered
nodes	pulls up the "node" menu

Nodes Menu

load nodes	loads pulls up previously saved nodes
save nodes	saves nodes
cancel/done	gets rid of the nodes menu

Parcellation menu

Edit parc lines	allows you to go back and edit parc lines
Save extract load	pulls up labeling menu for parcellation
Alt config	changes screen view into a combination of both Tile Display and CardViews
show label	gives actual names of parcellation units on labeled images

Parcellation Labeling Mode

List	show list of labels
Next	scroll through more labels
Reset	return to original labeling list
arrow next to auxlab	right click on the arrow to give a list of labels not on the regular menu, e.g. temporal pole, basal forebrain, and ??? Scroll through and left click on desired label
f	skip a PU in the sequence
b	go back to a PU in the sequence
Hemis	switch hemispheres in labeling sequence
Save	save labels
+ and - buttons	scroll through images

Parcellation Functions Summary

There are more buttons and functions that may not be listed here. These are either not useful for our method of parcellation, or are a mystery. Feel free to play around. Unless otherwise specified, "click" refers to a left mouse button click.

Sulci

FUNCTION	TO USE	OTHER
Changing from CardViews screen (single image) to TileDisplay (multiple images)	Click on **TILEDISPLAY** button and then click **GO**, multiple images will be presented.	Click on the **CARDVIEWS** button to return to single image.
Changing the view and range of slices	To change view, click on the box adjacent to the view you wish to display (**COR, SAG, AXI**). The range of slices to be displayed is shown on the bars above these boxes. Clicking on the bar and dragging left or right can change the range. Clicking on the arrowheads next to the view labels will also change range. When you have selected the desired range click on the **GO** button.	Clicking the **SET** button before the **GO** button will give you a set of slices around the selected slice number (which can be selected by clicking on the slice). Clicking on the **ZOOM** button will zoom in on the set making the images bigger. Click on the **ZOOM** button again to return images to the original size.
Saving the range of slices	Click on one of the **SAVE** buttons below **OSM**. In order to recall the views click on the **RCL** button next to the **SAVE** button. *Clicking on the arrow above save icon will produce more save icons.*	
Manipulating the brightness/contrast of the screen	Middle click and drag (move cursor while holding mouse button) upward to brighten, downward to darken, left to decrease the contrast, and right to increase the contrast. Middle click again to select desired brightness/contrast.	
Changing the name and color of draw pen	Press the "s" key (with cursor in main frame) and click on desired pen or color.	In order to return to image, press the "space bar" key or click on the **GO** button. *If you press the "space bar" key in TileDisplay you must have saved the screen of images, or the screen will come back blank and possibly crash cardviews.*

Drawing sulci	Right click to enter draw mode. Left Click on where you want the line to begin, and then Left Click again where you want the line to end. Continue to Left Click to connect each point with the last. Right Click to "terminate" draw mode. *You must exit out of draw out of each line you draw in order to draw a new line.*	
Erasing sulci	In order to erase a whole line, click on the line and drag (move cursor while holding the mouse button) the line out of the screen. Middle Click to erase each successive segment of the last line drawn. *Middle click only works if you have not yet terminated the draw mode after drawing a line.*	
Using the Cross-hair reference point	Left Click on point in question and then click on the **CREATE** button. You can move this point by left clicking on the points in question.	Click on the **DESTROY** button to get rid of crosshair.
Recalling sulci lines *They tend to disappear when you change screens.*	Click on the arrow next to the **SULCI** icon.	
Saving sulci	Click on **WRITE SULCI**, a new window will appear with the options **OVERWRITE** and **CANCEL**. Click on the **OVERWRITE** button.	*All sulci must be recalled before saving.* *Overwriting new sulci will, of course, erase the previously saved sulci.*

Nodes

FUNCTION	TO USE	OTHER
Recalling segmentation outlines *This is not necessary but sometimes useful when setting nodes.*	Enter the segmentation prefix on the **PREFIX** line (i.e. rjml). Click on the arrow next to **OTL**. You can switch back and forth between the image and outlines by using the **TOGGLE** button.	You can change the color of the outlines by right clicking on the arrow (next to **OTL**), a menu with red, green, white, yellow, and black will appear. Click on the color you desire.
Setting nodes	Click on the exact voxel you want node to be set on the image. Hit the "n" key to bring up the node menu. Click on the numbers next to the name of the desired node.	Hit the "space bar" or click the **GO** button to return to the images. *As with the sulci menu you must make sure the images are saved or you will return to a blank screen or crash cardviews if you use the "space bar."*
Saving nodes	Click the **NODES** button. A new window will appear with the options **LOAD NODES** and **SAVE NODES**. Click the **SAVE NODES** button.	Click on the **DONE/CANCEL** button to close the node window.
Changing nodes	Click on the voxel you would like to change the node to. Hit the "n" key and click on the old numbers of the node you would like to change.	Hit "u" key to undo the last change.
Printing nodes	Pull up nodes screen by pressing the "n" key. Right click on the background behind the cardviews window (you may need to move the window a little), this will bring up a program menu. Select **"snapshot"** to bring up the snapshot menu. Click on **REGION** and an arrow will appear. Click and drag to include the whole nodes grid in a box. Middle click to take the snapshot (right clicking will cancel the snapshot). Click the **PRINT** button to print the snapshot.	*This process is based on the Solaris shell for Sun Workstations and may not be applicable to other user environments.*

Parcellation/Labeling

FUNCTION	TO USE	OTHER
Labeling mode	While in TileDisplay, check the boxes next to **LINES** and **LABEL**. Checking the **LINES** box will allow you to draw parcellation lines, or bring up parcellation lines drawn in the past. Checking the **LABEL** box will bring up the labeling menu. *You must have the coronal view checked for this to work properly*	To get rid of the lines and labeling menu (i.e. return to normal TileDisplay), click the **LINES** and **LABEL** boxes again to uncheck them.
Alternative configuration mode (combines TileDisplay with cardviews and labeling menu to allow for easy cross-referencing, comparison, and labeling).	Click on the **ALT CFG** button in the labeling menu.	Click on the **ALT CFG** in the labeling menu to return to TileDisplay (the labeling menu will still be present). Above the small coronal view in ALT CFG the numbers of the slices for each view with the most sulci lines draw on it will appear. Click on any of these numbers to recall this slice for quick referencing.
Scrolling through image slices	The slice number, which you are presently working on, will be displayed next to **SLICE**. You can either scroll through the slices by clicking on the arrows next to this number or you can click on the **+** or **-** buttons to change the slice number.	You can also enter in the new slice number and press enter to move to a slice right away.
Drawing parcellation lines	Similar to drawing sulci lines, right click to enter draw mode. Click on where you want the line to begin, and then click again where you want the line to end. Continue to click to connect each point with the last. You cannot click and drag to draw parcellation lines.	
Erasing parcellation lines	Similar to erasing sulci lines, left click on the line and drag the line out of the screen to erase a whole line. Middle click to erase each successive increment of the last line drawn. *Middle click only works if you*	

	have not yet terminated the draw mode after drawing the particular line or increment you wish to erase.	
Entering labeling mode	After drawing parcellation lines, click on the **SAVE EXTRACT LOAD** button. A more extensive menu will appear with label names (calculated from your nodes) on the left edge of the menu box (the **R** or **L** on the top denotes the hemisphere) , and a few new buttons. A yellow box will also appear around one of the parcellation units (PU) on your image.	Click on **EDIT PARC LINES** to return to the original menu and edit your parcellation lines.
Labeling the parcellation units	The PU with the yellow box around it will be the PU you are labeling. Choose the proper label from the list and click on it. This will give a color to your PU and move the yellow box to the next PU in question. You can skip or go back to a PU by either clicking on the new PU in the image, or clicking on the forward button (**F)** or the back button (**B**). These will move the yellow box around the PUs sequentially.	The program will automatically switch from one hemisphere to the other in sequence (after one side is labeled it will switch to the other). However, if you wish to switch hemispheres you can do so either by clicking on the other hemisphere in the image, or by clicking on the **HEMIS** button.
Choosing a label that is not given on the menu	Click on the **LIST** button to bring up a list of all of the labels (this will appear where the original label list was). Click on **NEXT** button to scroll through all of the labels. Click on the desired label for the PU.	Click on the **RESET** button or click on any PU in the image to return to the original label menu.
Labeling a section or parcellation unit as temporal pole, basal forebrain, or "???"	Right click on the arrow next to **AUXLAB**, and drag down the menu. Click on the appropriate label.	
Saving labels	Click on the **SAVE** button next to the **+** and **-** buttons.	
Showing the label names on the image	Click on the **SHOWLBL** button.	Click on the **SHOWLBL** button again to get rid of labels.

Sulci Definitions

central sulcus (ce)
Divides the frontal and parietal lobes. It starts at the vertex of the brain where it is usually visible on the medial surface and courses anteroventrally to a point near the superior lip of the sylvian fissure. It may be separated from the sylvian fissure by the subcentral gyrus, and is sometimes divided into superior and inferior segments.

precentral sulcus (prc)
Divides the precentral gyrus from the three frontal gyri. It follows a dorsomedial to ventrolateral path that is rostral and roughly parallel to the course to the central sulcus. Variably it continues onto the medial surface of the brain. The precentral sulcus is usually divided into superior and inferior segments.

postcentral sulcus (poc)
Lies posterior to the central sulcus and roughly parallels the central sulcus from the dorsal hemispheric margin to the sylvian fissure. The postcentral sulcus is frequently discontinuous.

superior frontal sulcus (sf)
Follows a course parallel to the interhemispheric plane throughout the frontal lobe and extends posteriorly to the precentral sulcus, which it meets at a right angle. It is best viewed on axial slices of the brain.

intraparietal sulcus (ip)
Follows a roughly transaxial course which partitions the superior and inferior parietal lobules (the superior parietal lobule is SPL. The inferior parietal lobule does not exist as a single parcellation unit in our system but is rather composed of: SGa, SGp, AG, PO). Rostrally it meets the postcentral sulcus. Posteriorly it continues in the occipital lobe and sometimes is called the intraoccipital sulcus. It may be segmented.

cingulate sulcus (ci)
Follows a course parallel to the corpus callosum. Posteriorly, it courses dorsally and terminates near the hemispheric margin caudal to the central sulcus.

paracingulate sulcus (pa)
Lies just in front of and parallel to the cingulate gyrus. It is often discontinuous.

subparietal sulcus (sp)
Mainly follows a parallel to the corpus callosum. Anteriorly it originates at the point of the upward angulation of the marginal sulcus. Posteriorly, it extends toward the anterior part of the calcarine sulcus. It intersects the cingulate sulcus at its most dorsal point.

calcarine sulcus (calc)
Extends from the occipital pole to a point just below and anterior to the splenium of the corpus callosum.

parietooccipital sulcus (po)
Follows a typical course from a dorso-caudal point at the hemispheric margin, to an anteroventral point at the junction with the calcarine sulcus.

cuneal sulcus (cu)
Is located within the cuneal region, superior and parallel to the calcarine sulcus. There is usually an additional sulcus above the cuneal sulcus within this region (the cuneal is the sulcus closest to the calcarine sulcus).

callosal sulcus (ca)
Defines the margin of the corpus callosum with cortex throughout the full extent of the commissure. This sulcus is usually not traced.

circular sulcus of the insula (cir)
Lying in the depth of the sylvian fissure, is defined throughout its circumference by the origins of the perisylvian opercula. It is optimally visualized in the sagittal plane. The Sylvian fissure forms a deep depression, whose sides overlap the insula and constitute the lateral operculum.

inferior frontal sulcus (if)
Lies ventral to, and parallels the superior frontal sulcus. Posteriorly, it also meets the precentral sulcus at a right angle. The inferior central sulcus is best viewed on lateral sagittal slices of the brain.

posterior horizontal ramus of the Sylvian fissure (phr)
Is the dominant fissure of the lateral hemisphere. It is bordered inferiorly by the supratemporal plane and superiorly by the frontal and parietal opercula.

posterior ascending ramus of the Sylvian fissure (par)
Represents the axis of the supramarginal gyrus. It is the main caudal extension of the posterior horizontal ramus of the sylvian fissure. It angulates dorsally as it courses caudally.

anterior horizontal ramus of the Sylvian fissure (ahr)
Is the most rostrally continuing segment of the sylvian fissure. Caudally, it begins at a point immediately anterior to the inferior precentral sulcus. It then courses rostrally.

anterior ascending ramus of the Sylvian fissure (aar)
Also begins caudally at a point immediately anterior to the inferior precentral sulcus. From this point it courses dorsally and rostrally such that the aar and ahr form a "V" with the open end facing anteriorly. It sometimes intersects the inferior frontal sulcus.

superior temporal sulcus (st)
Lies ventral to and parallel to the posterior horizontal ramus of the sylvian fissure. Anteriorly it ends close to the temporal pole. Posteriorly it gives rise to the angular sulcus and the lateral occipital sulcus.

angular sulcus (ag)
Anteriorly, is continuous with the superior temporal sulcus. Posteriorly it arches dorsally such that it is caudal and parallel to the posterior ascending ramus of the sylvian fissure, extending to the hemispheric margin.

lateral occipital sulcus (lo)
The posterior continuation of the superior temporal sulcus, dividing the lateral occipital surface into OLs and OLi.

intermediate sulcus of Jensen (im)
Is a downward-projecting side branch of the intraparietal sulcus. It descends across the inferior parietal lobule.

inferior temporal sulcus (it)
Starts at the temporal pole below the superior temporal sulcus, dividing the parcellation unit T2 from T3.

olfactory sulcus (ol)
Lies just lateral to the medial hemispheric margin on the ventral surface of the brain follows a parasagittal course in ventral axial slices.

collateral sulcus (co)
Courses along the ventro-medial surface of the temporal and occipital lobes. It follows closely the parahippocampal gyrus anteriorly and the lingual gyrus posteriorly.

occipitotemporal sulcus (ot)
Follows an approximately parasagittal course just medial to the inferolateral margin of the hemisphere.

Heschl's sulcus (he)
Is the sulcus immediately lateral to the Heschl gyrus.

first transverse sulcus (ftr)
Is the sulcus immediately medial to the Heschl's gyrus.

Parcellation Unit Definitions

AG	Angular Gyrus
CALC	Intracalcarine Cortex
CGa	Cingulate Gyrus, anterior division
CGp	Cingulate Gyrus, posterior division
CN	Cuneal Cortex
CO	Central Opercular Cortex
F1	Superior Frontal Gyrus
F2	Middle Frontal Gyrus
F3o	Inferior Frontal Gyrus, pars opercularis
F3t	Inferior Frontal Gyrus, pars triangularis
FMC	Frontal Medial Cortex
FO	Frontal Operculum Cortex
FOC	Frontal Orbital Cortex
FP	Frontal Pole
H	Heschl's Gyrus (includes H1 and H2)
INS	Insular Cortex
JPL (SMC)	Juxtapositional Lobule Cortex (formerly Supplementary Motor Cortex)
LG	Lingual Gyrus
OF	Occipital Fusiform Gyrus
OLi	Lateral Occipital Cortex, inferior division
OLs	Lateral Occipital Cortex, superior division
OP	Occipital Pole
PAC	Paracingulate Gyrus
PCN	Precuneous Cortex
PHa	Parahippocampal Gyrus, anterior division
PHp	Parahippocampal Gyrus, posterior division
PO	Parietal Operculum Cortex
POG	Postcentral Gyrus
PP	Planum Polare
PRG	Precentral Gyrus
PT	Planum Temporale
SC	Subcallosal Cortex
SCLC	Supracalcarine Cortex
SGa	Supramarginal Gyrus, anterior division
SGp	Supramarginal Gyrus, posterior division
SPL	Superior Parietal Lobule
T1a	Superior Temporal Gyrus, anterior division
T1p	Superior Temporal Gyrus, posterior division
T2a	Middle Temporal Gyrus, anterior division
T2p	Middle Temporal Gyrus, posterior division
T3a	Inferior Temporal Gyrus, anterior division
T3p	Inferior Temporal Gyrus, posterior division
TFa	Temporal Fusiform Cortex, anterior division
TFp	Temporal Fusiform Cortex, posterior division
TO2	Middle Temporal Gyrus, temporooccipital part
TO3	Inferior Temporal Gyrus, temporooccipital part
TOF	Temporal Occipital Fusiform Cortex
TP	Temporal Pole

Atlas of the Parcellated Brain