

available at [www.sciencedirect.com](http://www.sciencedirect.com)journal homepage: [www.elsevier.com/locate/cortex](http://www.elsevier.com/locate/cortex)

## Special issue: Research report

# A diffusion tensor imaging tractography atlas for virtual in vivo dissections

Marco Catani<sup>a,b,\*</sup> and Michel Thiebaut de Schotten<sup>a,b,c</sup>

<sup>a</sup>Natbrainlab, Section of Brain Maturation, Institute of Psychiatry, King's College London, London, UK

<sup>b</sup>Centre for Neuroimaging Sciences, Institute of Psychiatry, King's College London, London, UK

<sup>c</sup>CENIR – Centre de Neuroimagerie de Recherche, Hopital de la Salpetriere, 75651 Paris, France

### ARTICLE INFO

#### Article history:

Received 6 April 2008

Reviewed 14 April 2008

Revised 17 April 2008

Accepted 18 April 2008

Published online 23 May 2008

#### Keywords:

Diffusion Tensor Imaging (DTI)

Tractography

White matter atlas

Connections

### ABSTRACT

Diffusion tensor imaging (DTI) tractography allows perform virtual dissections of white matter pathways in the living human brain. In 2002, Catani et al. published a method to reconstruct white matter pathways using a region of interest (ROI) approach. The method produced virtual representations of white matter tracts faithful to classical post-mortem descriptions but it required detailed a priori anatomical knowledge. Here, using the same approach, we provide a template to guide the delineation of ROIs for the reconstruction of the association, projection and commissural pathways of the living human brain. The template can be used for single case studies and case-control comparisons. An atlas of the 3D reconstructions of the single tracts is also provided as anatomical reference in the Montreal Neurological Institute (MNI) space.

© 2008 Elsevier Masson Srl. All rights reserved.

## 1. Introduction

The possibility of performing virtual dissections of white matter tracts and visualizing pathways in the living human brain is one of the most promising applications of diffusion tensor imaging (DTI) tractography (Catani and Mesulam, 2008a, this issue; Catani, 2006). Current DTI tractography methods require the delineation of regions of interest (ROIs) as starting “seed points” for tracking (Jones, 2008, this issue). One approach for ROIs delineation is the automatic application of normalized cortical or subcortical masks to single brain data sets (see for example, Lawes et al., 2008). The use of cortical masks is of particular help when trying to reduce tractography analysis time and operator-dependent biases. But these

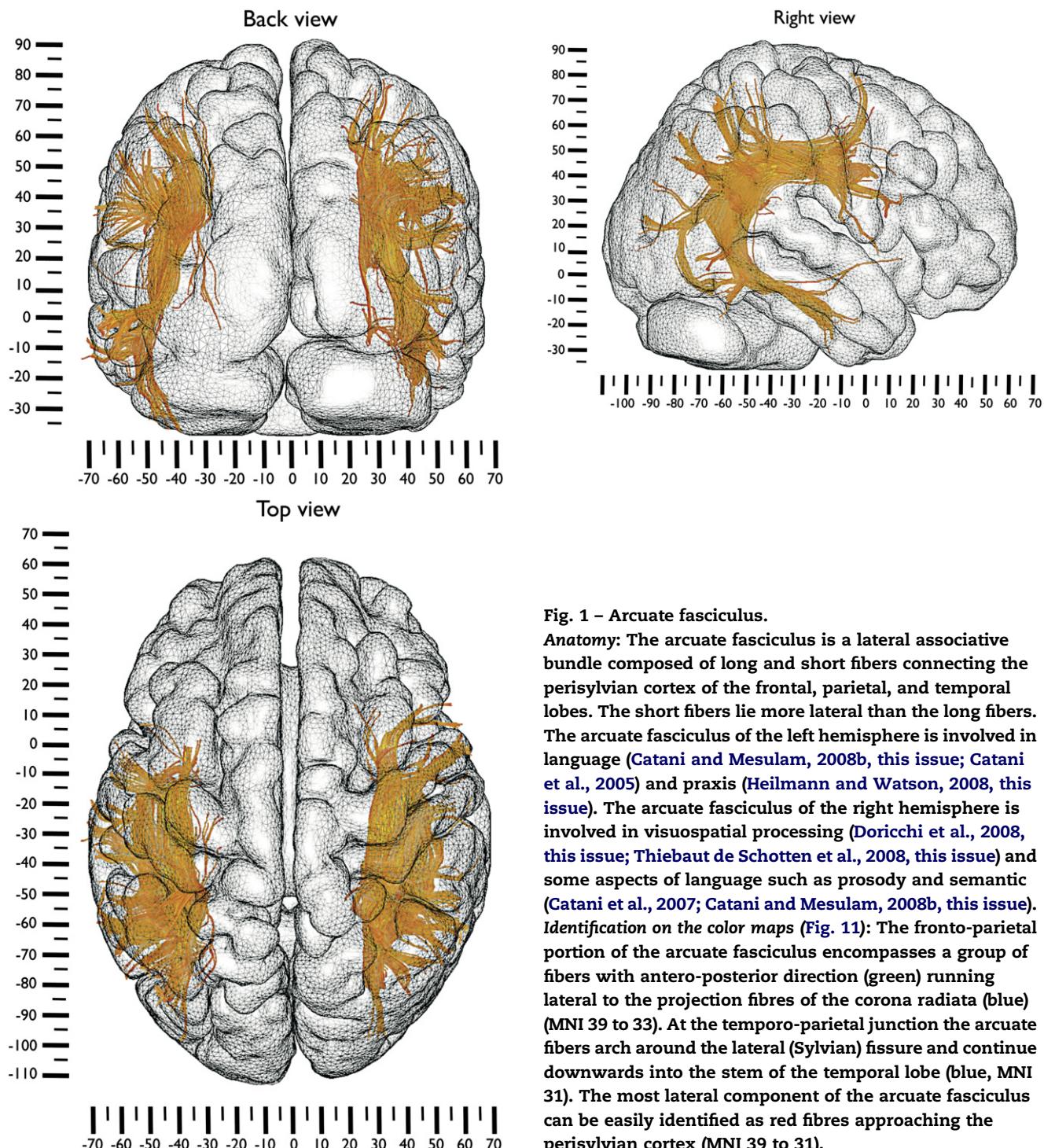
methods perform poorly when applied to pathological brains (e.g., when the anatomy is distorted by the underlying pathological process) or when the experimenter aims at describing inter-individual variability in tract anatomy (e.g., studying differences in the cortical projections of an individual tract in the normal population). Also the use of cortical masks is prone to generate artefactual reconstructions of tracts due to high uncertainty of the fiber orientation in the cortical voxels or surrounding white matter (Jones, 2003; Jones, 2008, this issue). An alternative strategy is to define the ROIs manually. This approach may overcome some of the problems mentioned above and has been successfully used in several tractography studies (Conturo et al., 1999; Concha et al., 2005; Basser et al., 2000; Catani et al., 2002; Mori et al., 2000). One limiting step

\* Corresponding author. Centre for Neuroimaging Sciences, Institute of Psychiatry, King's College London, P.O. Box 89, De Crespigny Park, London SE5 8AF, UK.

E-mail address: [m.catani@iop.kcl.ac.uk](mailto:m.catani@iop.kcl.ac.uk) (M. Catani).

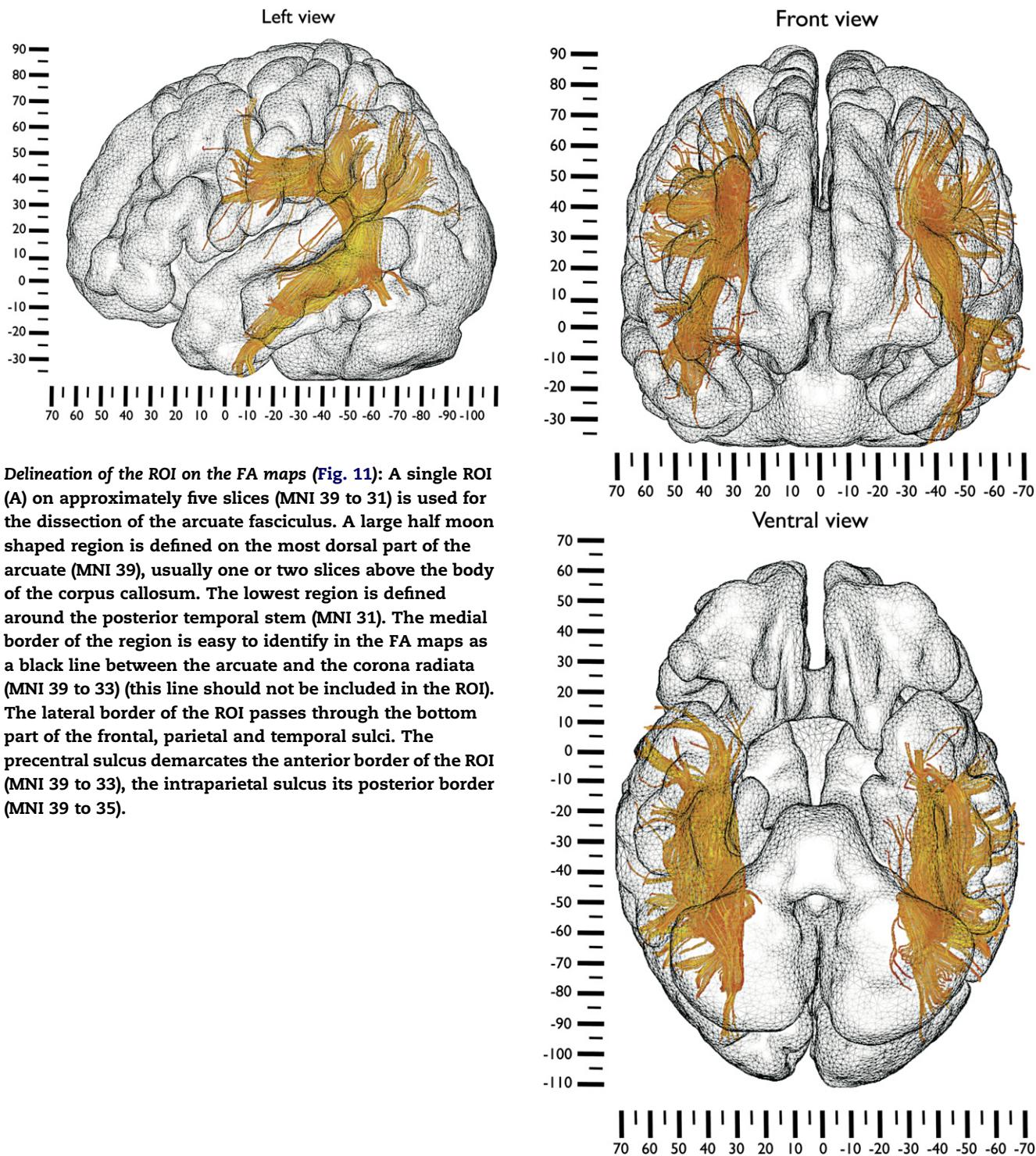
0010-9452/\$ – see front matter © 2008 Elsevier Masson Srl. All rights reserved.

[doi:10.1016/j.cortex.2008.05.004](https://doi.org/10.1016/j.cortex.2008.05.004)

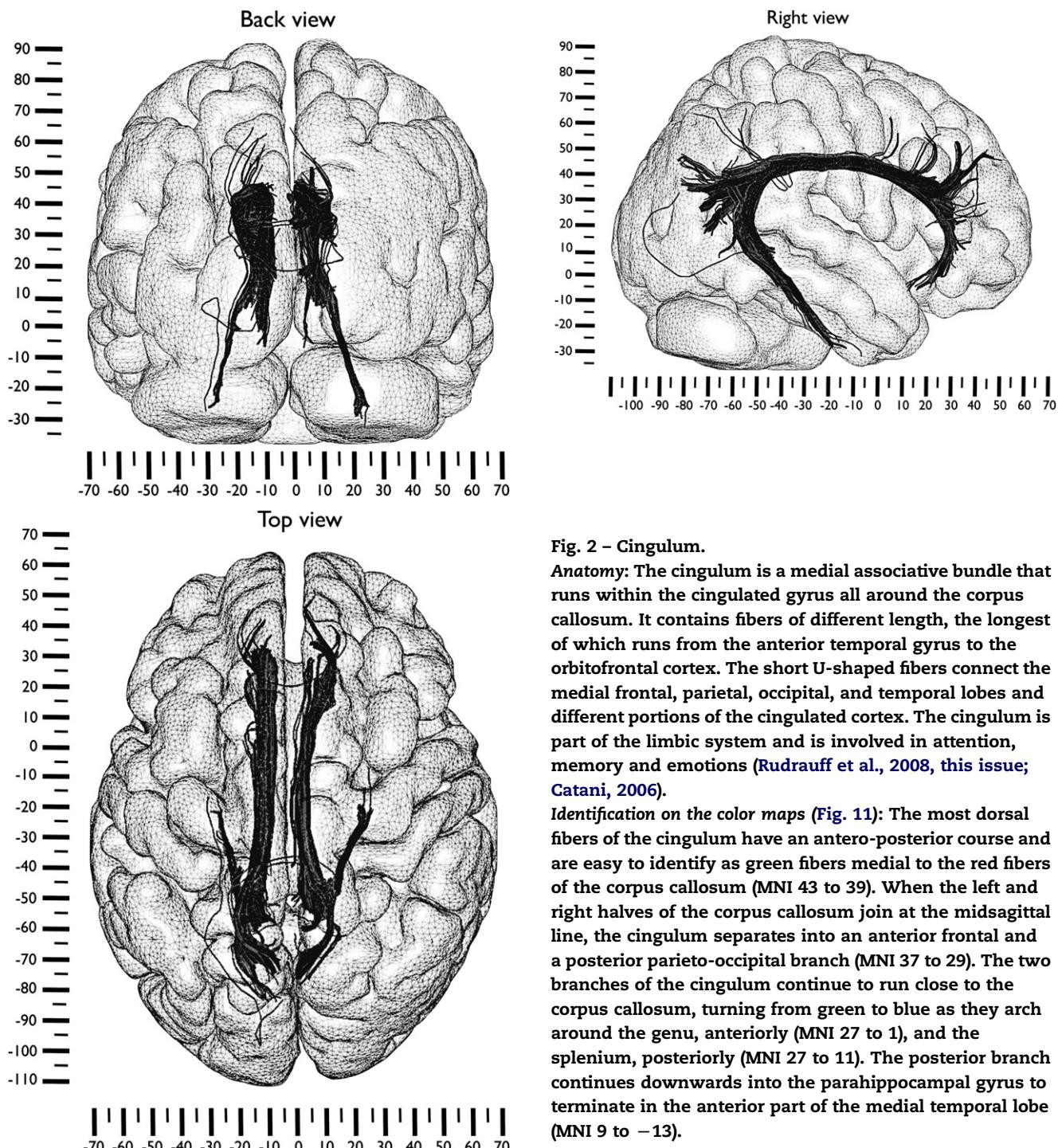


**Fig. 1 – Arcuate fasciculus.**

**Anatomy:** The arcuate fasciculus is a lateral associative bundle composed of long and short fibers connecting the perisylvian cortex of the frontal, parietal, and temporal lobes. The short fibers lie more lateral than the long fibers. The arcuate fasciculus of the left hemisphere is involved in language (Catani and Mesulam, 2008b, this issue; Catani et al., 2005) and praxis (Heilmann and Watson, 2008, this issue). The arcuate fasciculus of the right hemisphere is involved in visuospatial processing (Doricchi et al., 2008, this issue; Thiebaut de Schotten et al., 2008, this issue) and some aspects of language such as prosody and semantic (Catani et al., 2007; Catani and Mesulam, 2008b, this issue). **Identification on the color maps (Fig. 11):** The fronto-parietal portion of the arcuate fasciculus encompasses a group of fibers with antero-posterior direction (green) running lateral to the projection fibres of the corona radiata (blue) (MNI 39 to 33). At the temporo-parietal junction the arcuate fibers arch around the lateral (Sylvian) fissure and continue downwards into the stem of the temporal lobe (blue, MNI 31). The most lateral component of the arcuate fasciculus can be easily identified as red fibres approaching the perisylvian cortex (MNI 39 to 31).



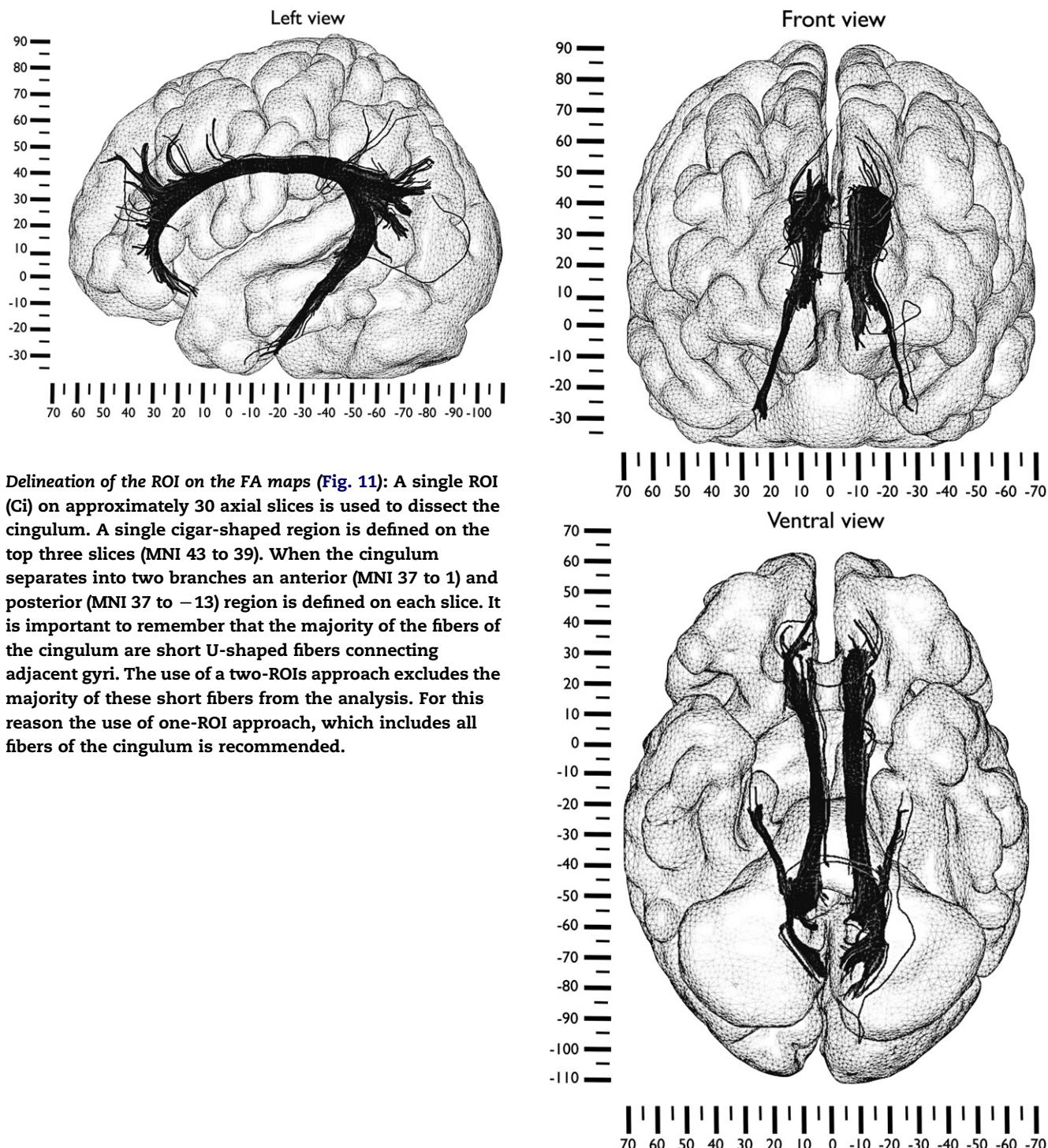
**Delineation of the ROI on the FA maps (Fig. 11):** A single ROI (A) on approximately five slices (MNI 39 to 31) is used for the dissection of the arcuate fasciculus. A large half moon shaped region is defined on the most dorsal part of the arcuate (MNI 39), usually one or two slices above the body of the corpus callosum. The lowest region is defined around the posterior temporal stem (MNI 31). The medial border of the region is easy to identify in the FA maps as a black line between the arcuate and the corona radiata (MNI 39 to 33) (this line should not be included in the ROI). The lateral border of the ROI passes through the bottom part of the frontal, parietal and temporal sulci. The precentral sulcus demarcates the anterior border of the ROI (MNI 39 to 33), the intraparietal sulcus its posterior border (MNI 39 to 35).



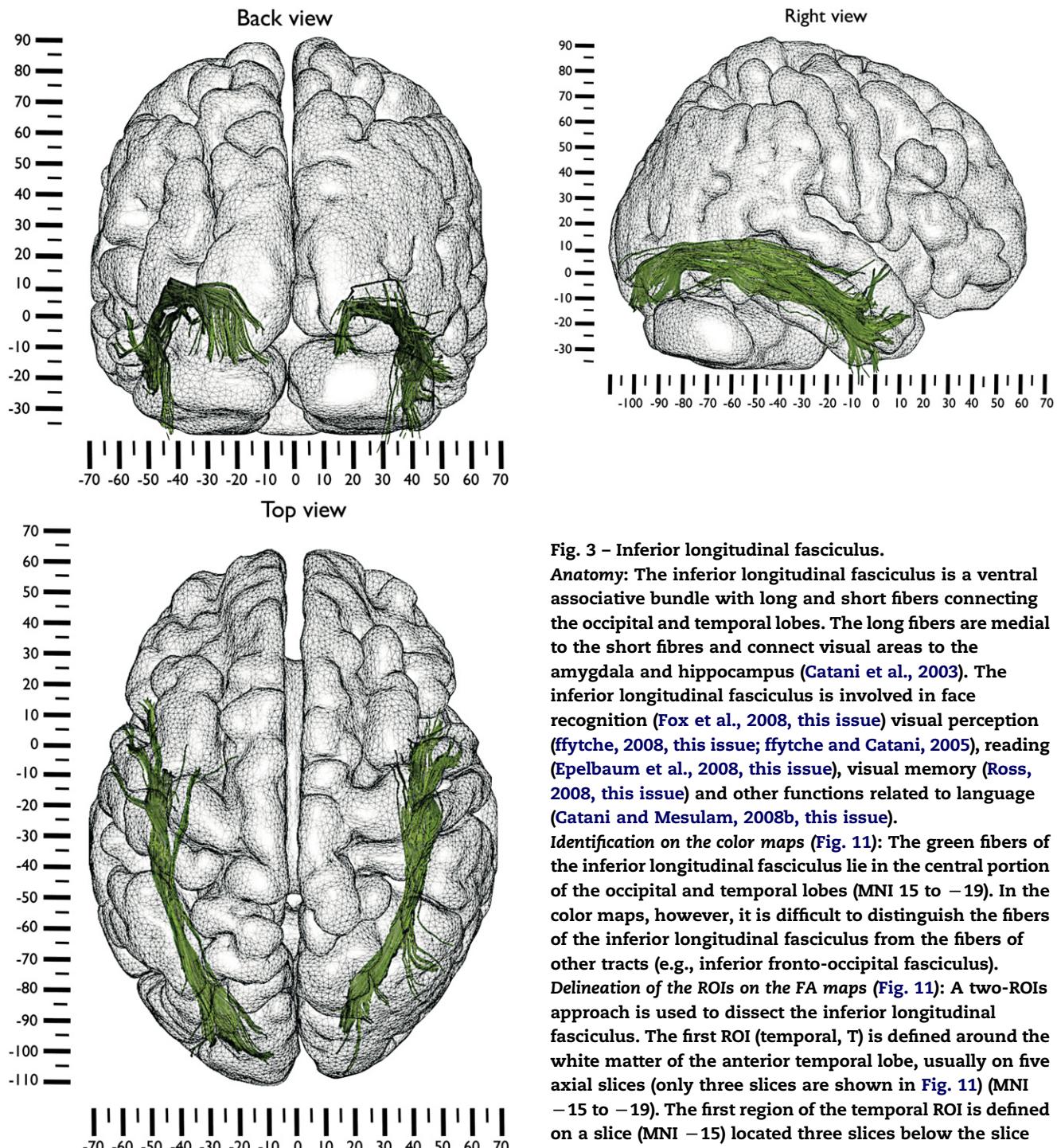
**Fig. 2 – Cingulum.**

**Anatomy:** The cingulum is a medial associative bundle that runs within the cingulated gyrus all around the corpus callosum. It contains fibers of different length, the longest of which runs from the anterior temporal gyrus to the orbitofrontal cortex. The short U-shaped fibers connect the medial frontal, parietal, occipital, and temporal lobes and different portions of the cingulated cortex. The cingulum is part of the limbic system and is involved in attention, memory and emotions (Rudrauff et al., 2008, this issue; Catani, 2006).

**Identification on the color maps (Fig. 11):** The most dorsal fibers of the cingulum have an antero-posterior course and are easy to identify as green fibers medial to the red fibers of the corpus callosum (MNI 43 to 39). When the left and right halves of the corpus callosum join at the midsagittal line, the cingulum separates into an anterior frontal and a posterior parieto-occipital branch (MNI 37 to 29). The two branches of the cingulum continue to run close to the corpus callosum, turning from green to blue as they arch around the genu, anteriorly (MNI 27 to 1), and the splenium, posteriorly (MNI 27 to 11). The posterior branch continues downwards into the parahippocampal gyrus to terminate in the anterior part of the medial temporal lobe (MNI 9 to -13).



**Delineation of the ROI on the FA maps (Fig. 11):** A single ROI (Gi) on approximately 30 axial slices is used to dissect the cingulum. A single cigar-shaped region is defined on the top three slices (MNI 43 to 39). When the cingulum separates into two branches an anterior (MNI 37 to 1) and posterior (MNI 37 to -13) region is defined on each slice. It is important to remember that the majority of the fibers of the cingulum are short U-shaped fibers connecting adjacent gyri. The use of a two-ROIs approach excludes the majority of these short fibers from the analysis. For this reason the use of one-ROI approach, which includes all fibers of the cingulum is recommended.

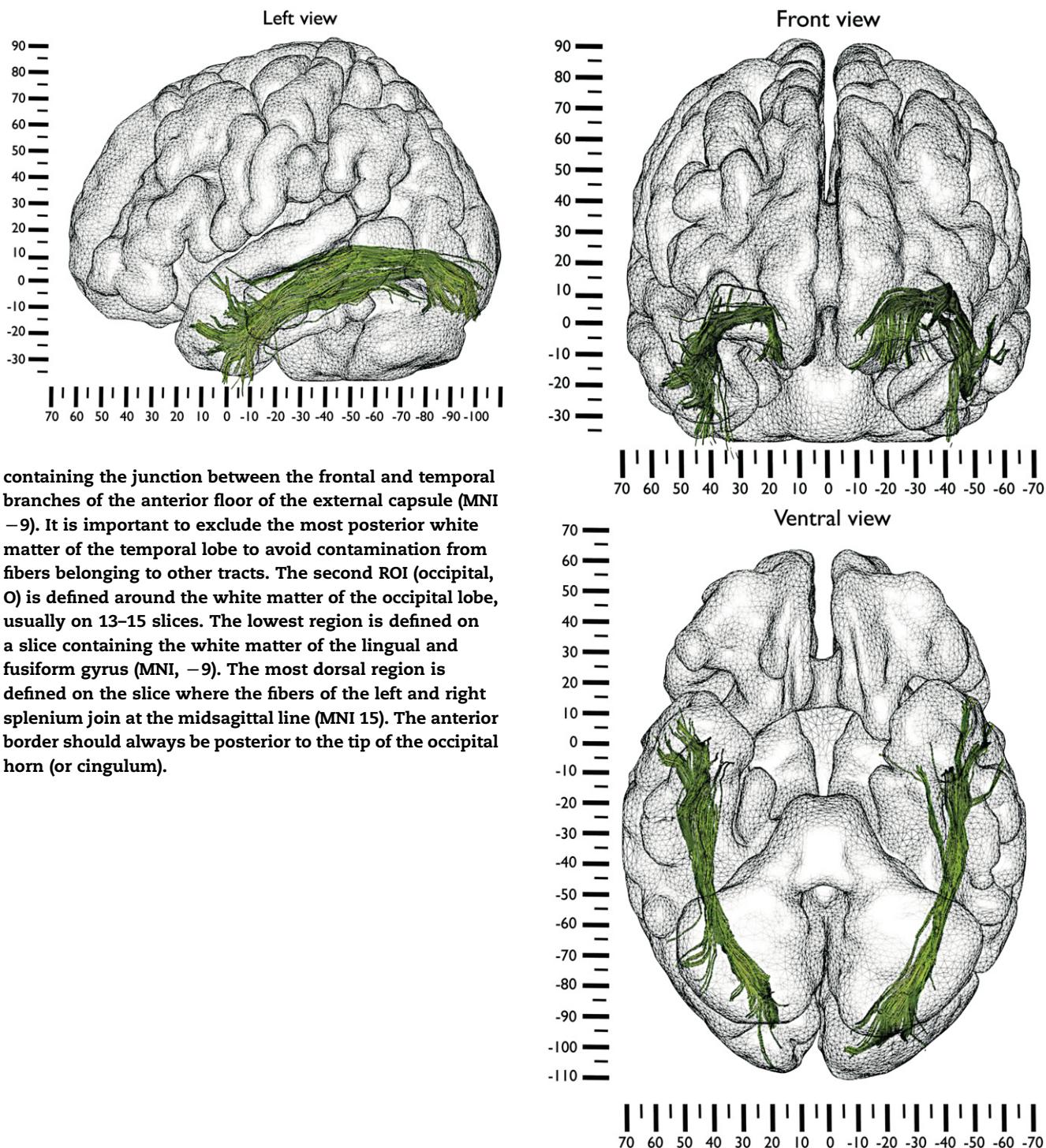


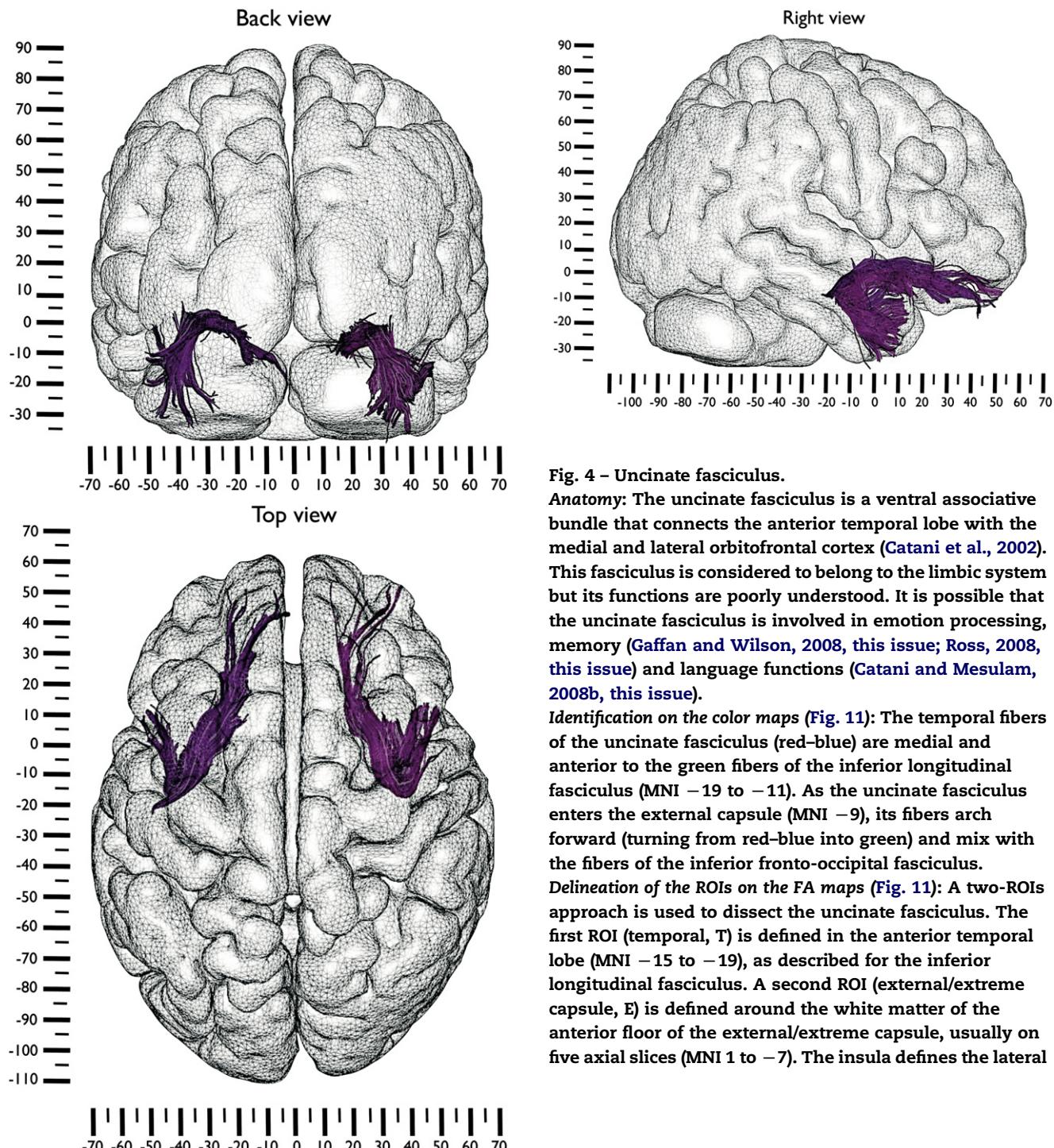
**Fig. 3 – Inferior longitudinal fasciculus.**

**Anatomy:** The inferior longitudinal fasciculus is a ventral associative bundle with long and short fibers connecting the occipital and temporal lobes. The long fibers are medial to the short fibres and connect visual areas to the amygdala and hippocampus (Catani et al., 2003). The inferior longitudinal fasciculus is involved in face recognition (Fox et al., 2008, this issue) visual perception (ffytche, 2008, this issue; ffytche and Catani, 2005), reading (Epelbaum et al., 2008, this issue), visual memory (Ross, 2008, this issue) and other functions related to language (Catani and Mesulam, 2008b, this issue).

**Identification on the color maps (Fig. 11):** The green fibers of the inferior longitudinal fasciculus lie in the central portion of the occipital and temporal lobes (MNI 15 to –19). In the color maps, however, it is difficult to distinguish the fibers of the inferior longitudinal fasciculus from the fibers of other tracts (e.g., inferior fronto-occipital fasciculus).

**Delineation of the ROIs on the FA maps (Fig. 11):** A two-ROIs approach is used to dissect the inferior longitudinal fasciculus. The first ROI (temporal, T) is defined around the white matter of the anterior temporal lobe, usually on five axial slices (only three slices are shown in Fig. 11) (MNI –15 to –19). The first region of the temporal ROI is defined on a slice (MNI –15) located three slices below the slice



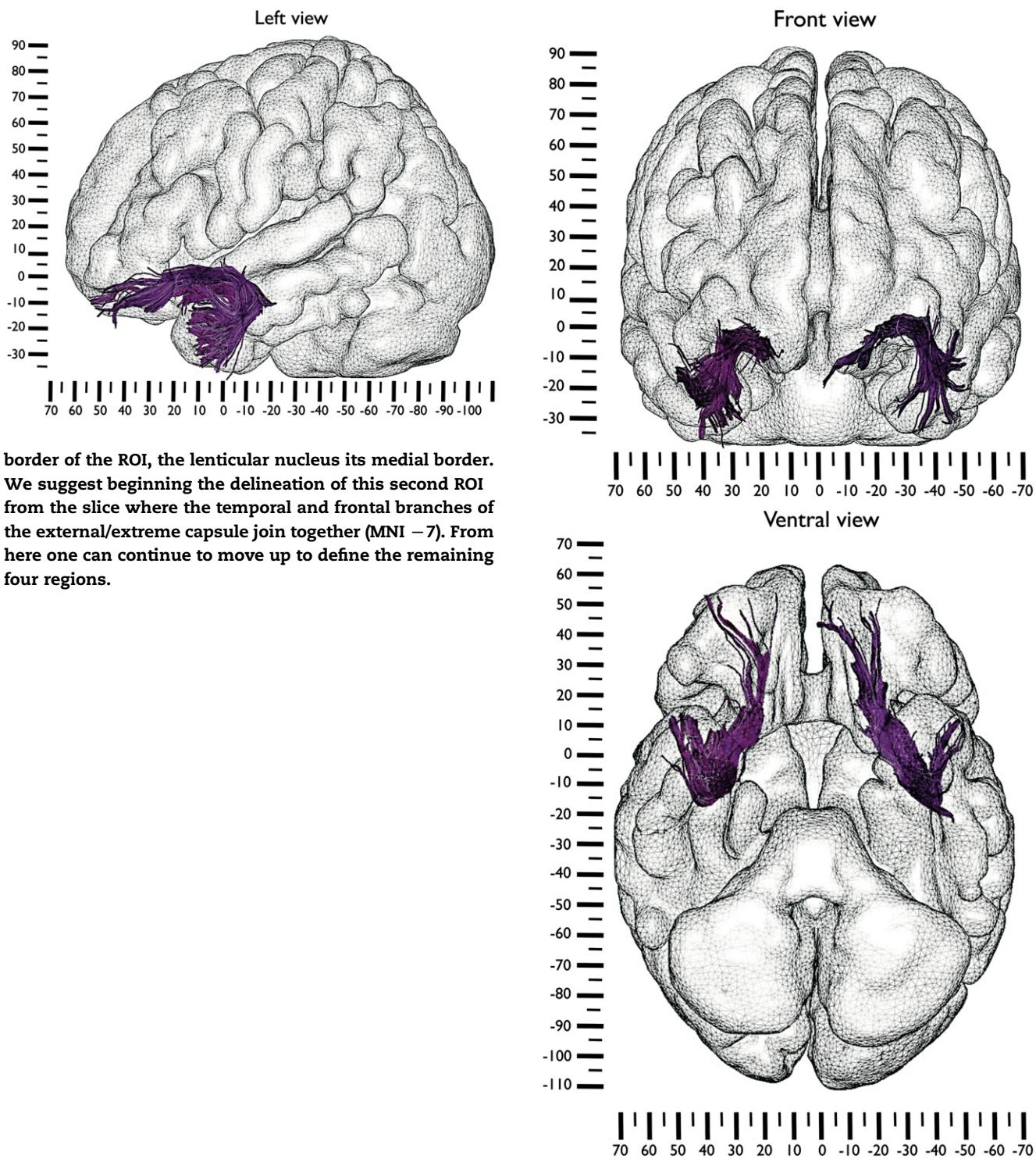


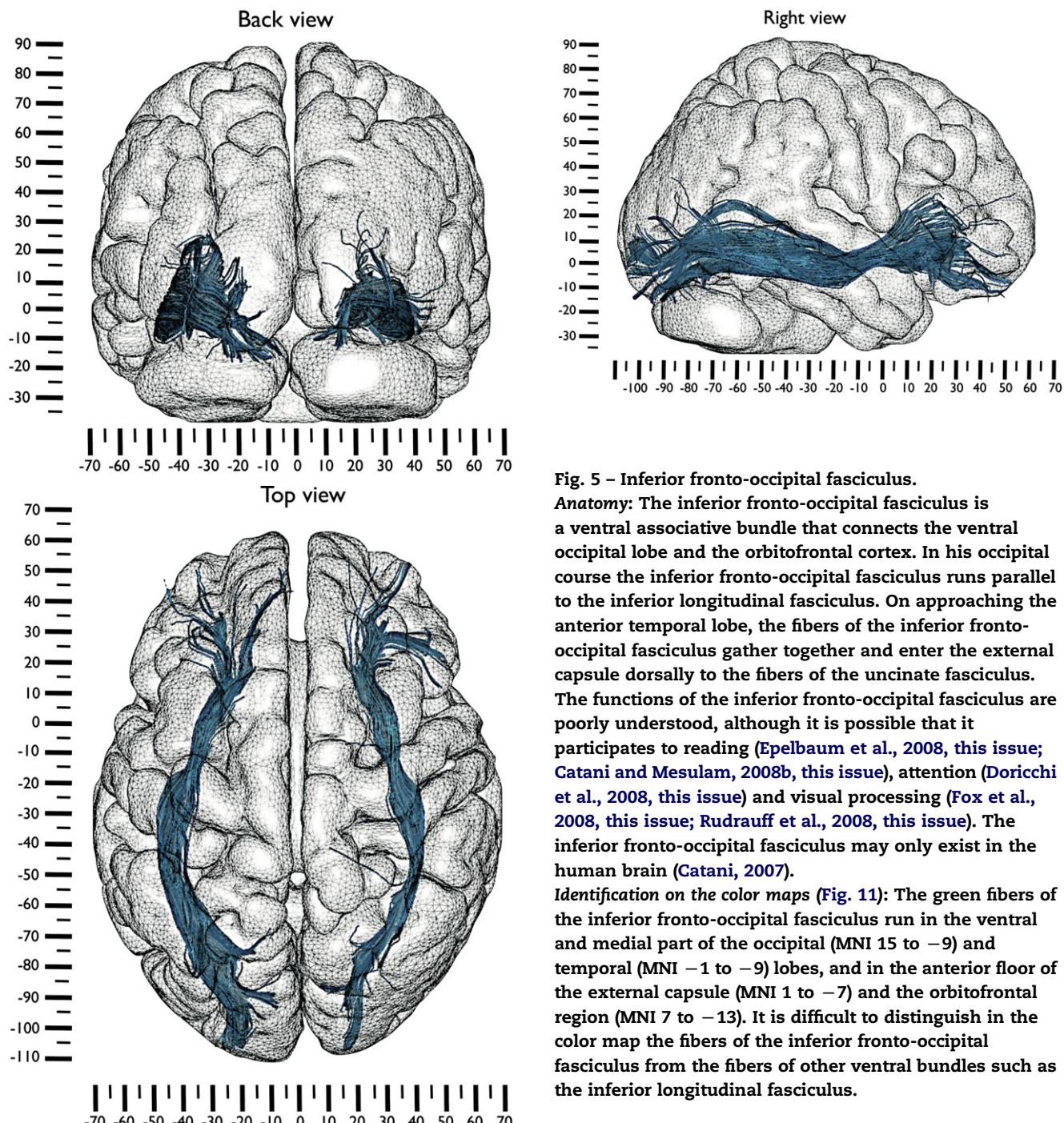
**Fig. 4 – Uncinate fasciculus.**

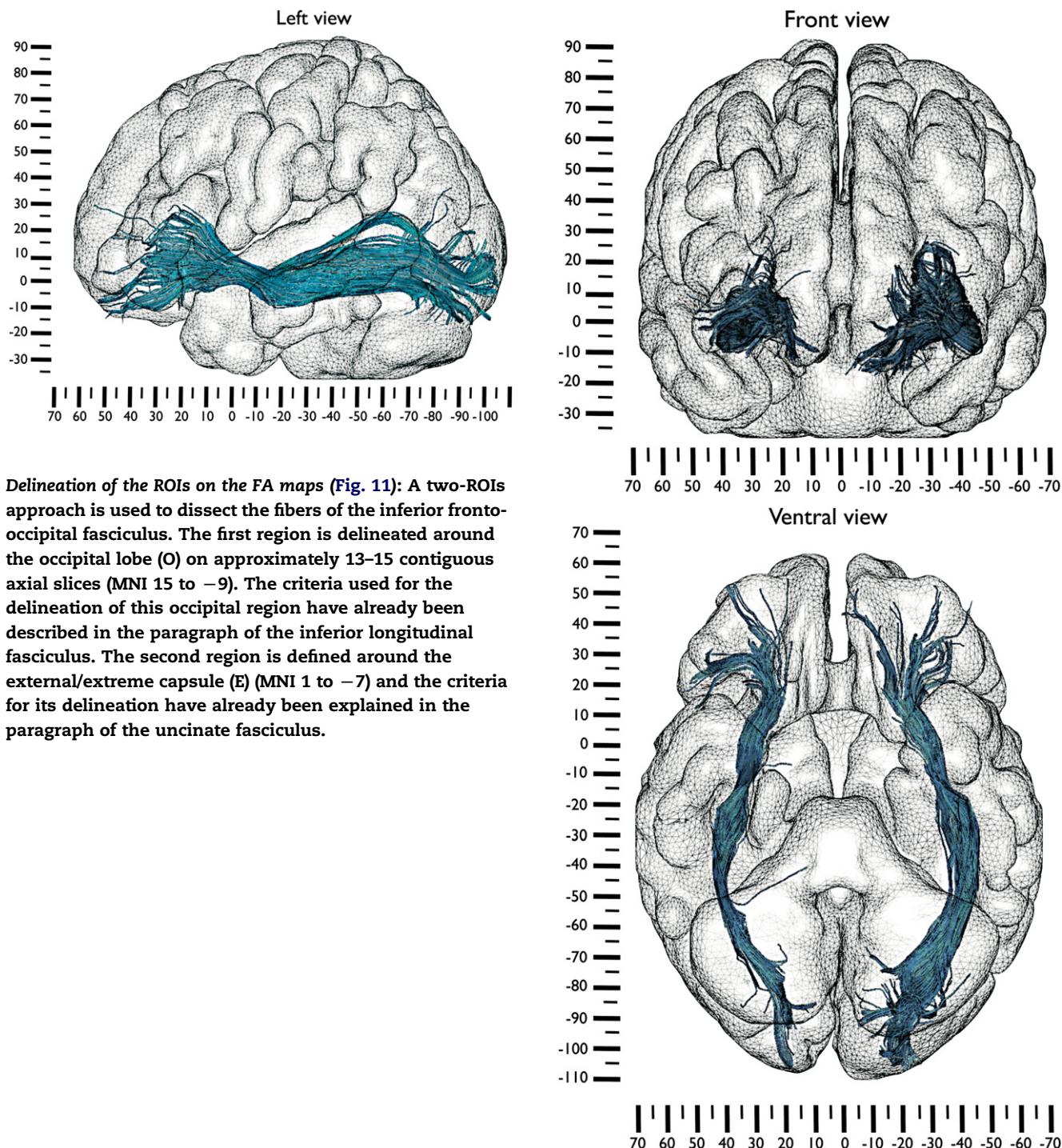
**Anatomy:** The uncinate fasciculus is a ventral associative bundle that connects the anterior temporal lobe with the medial and lateral orbitofrontal cortex (Catani et al., 2002). This fasciculus is considered to belong to the limbic system but its functions are poorly understood. It is possible that the uncinate fasciculus is involved in emotion processing, memory (Gaffan and Wilson, 2008, this issue; Ross, 2008, this issue) and language functions (Catani and Mesulam, 2008b, this issue).

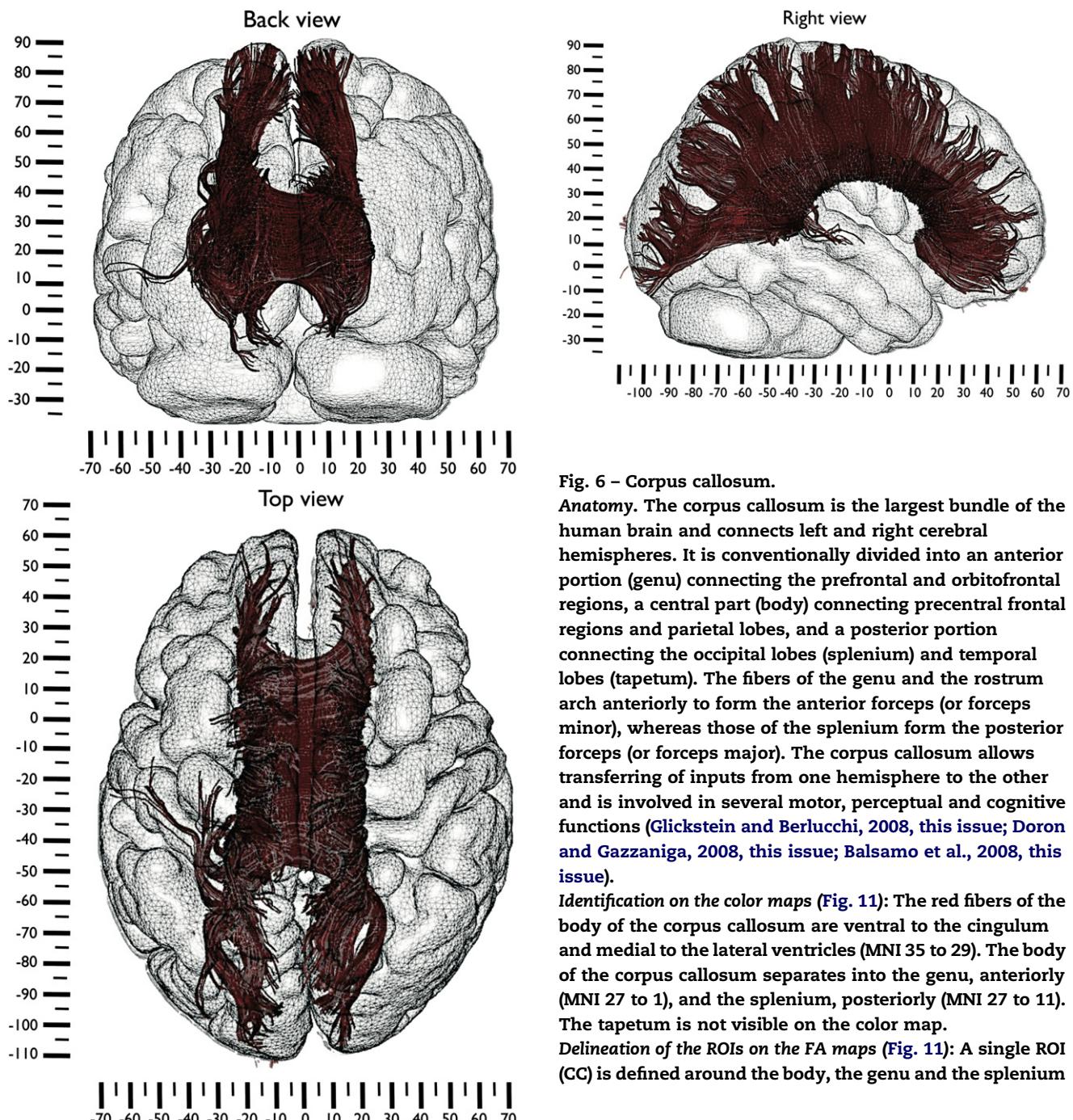
**Identification on the color maps (Fig. 11):** The temporal fibers of the uncinate fasciculus (red-blue) are medial and anterior to the green fibers of the inferior longitudinal fasciculus (MNI −19 to −11). As the uncinate fasciculus enters the external capsule (MNI −9), its fibers arch forward (turning from red-blue into green) and mix with the fibers of the inferior fronto-occipital fasciculus.

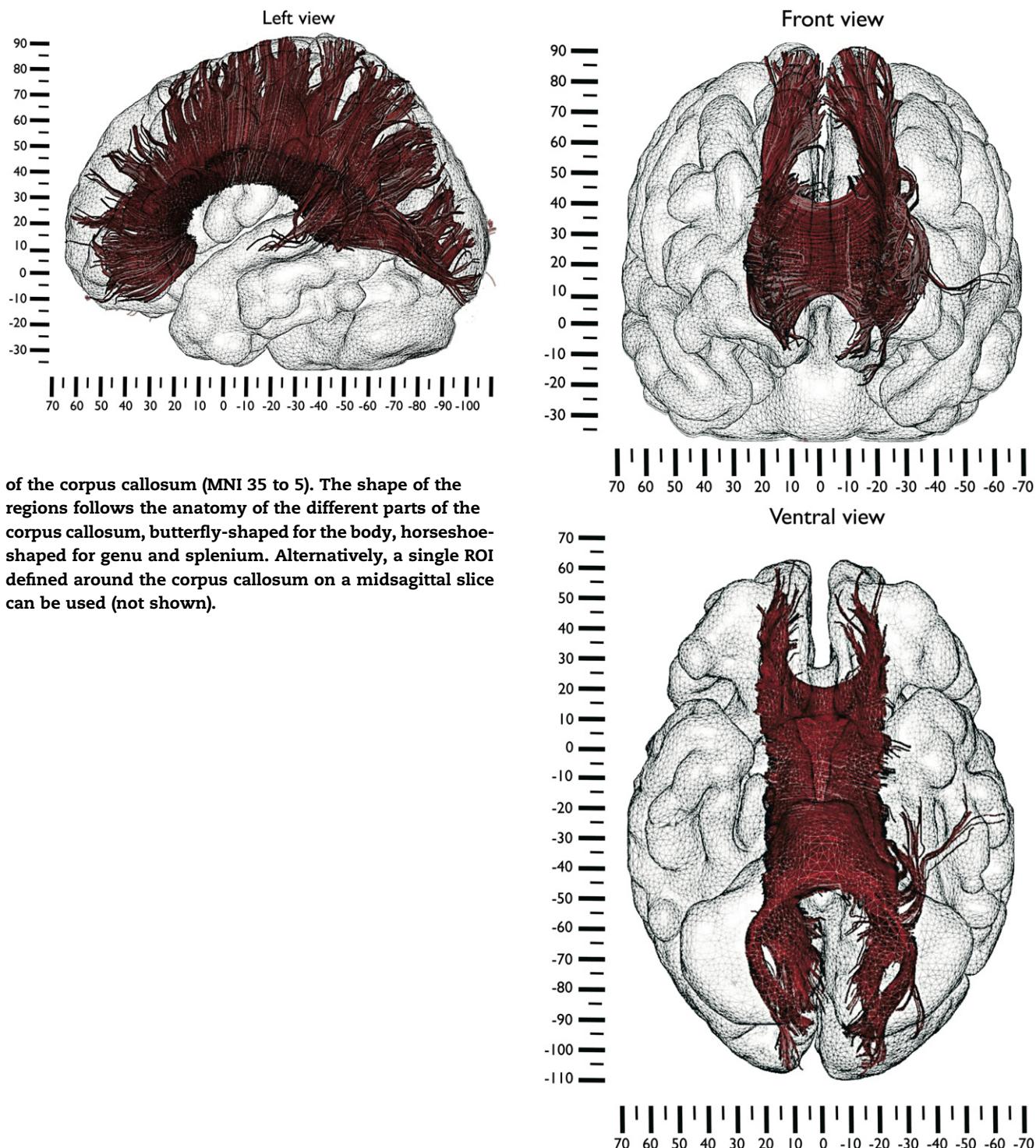
**Delineation of the ROIs on the FA maps (Fig. 11):** A two-ROIs approach is used to dissect the uncinate fasciculus. The first ROI (temporal, T) is defined in the anterior temporal lobe (MNI −15 to −19), as described for the inferior longitudinal fasciculus. A second ROI (external/extreme capsule, E) is defined around the white matter of the anterior floor of the external/extreme capsule, usually on five axial slices (MNI 1 to −7). The insula defines the lateral

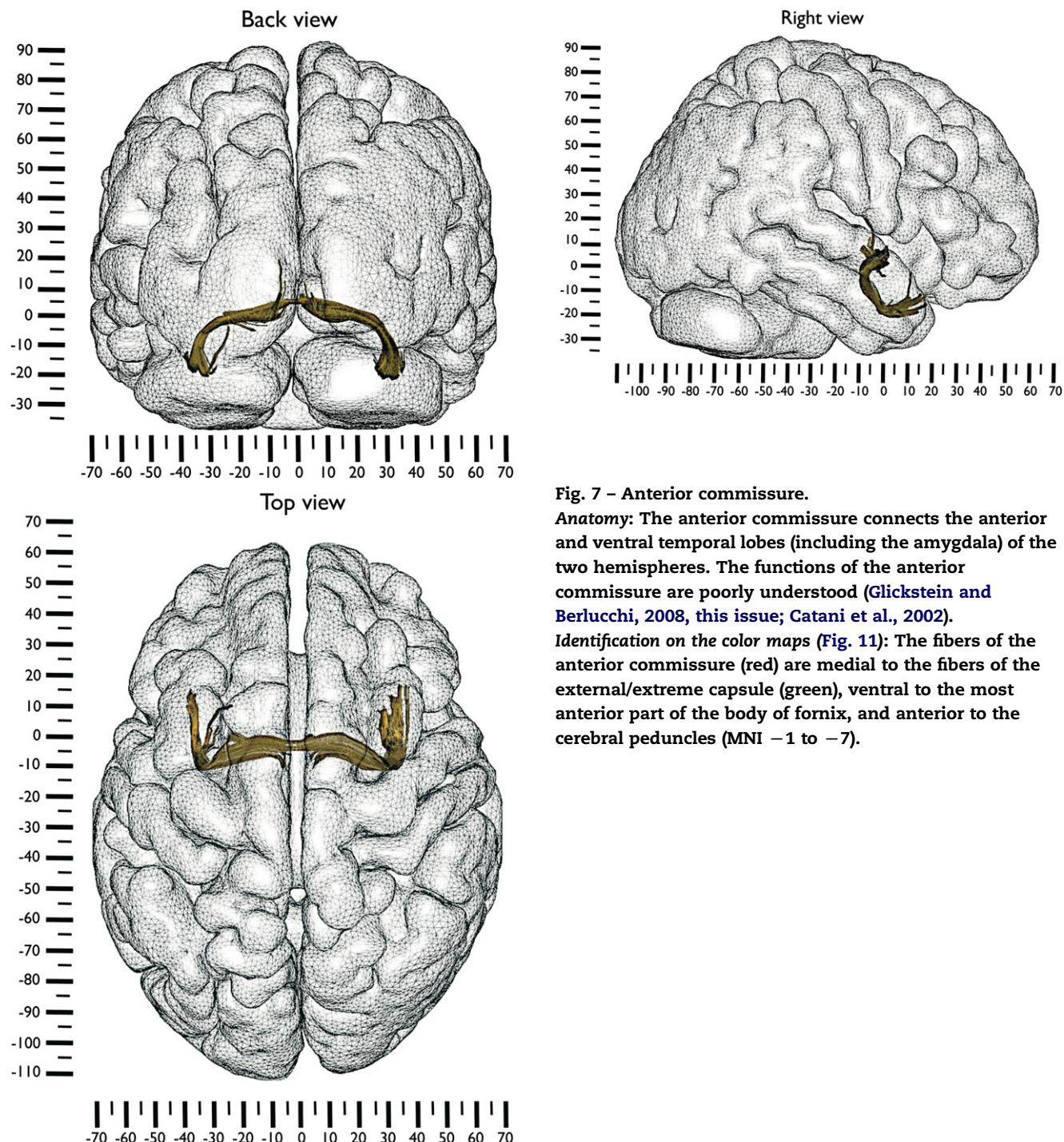








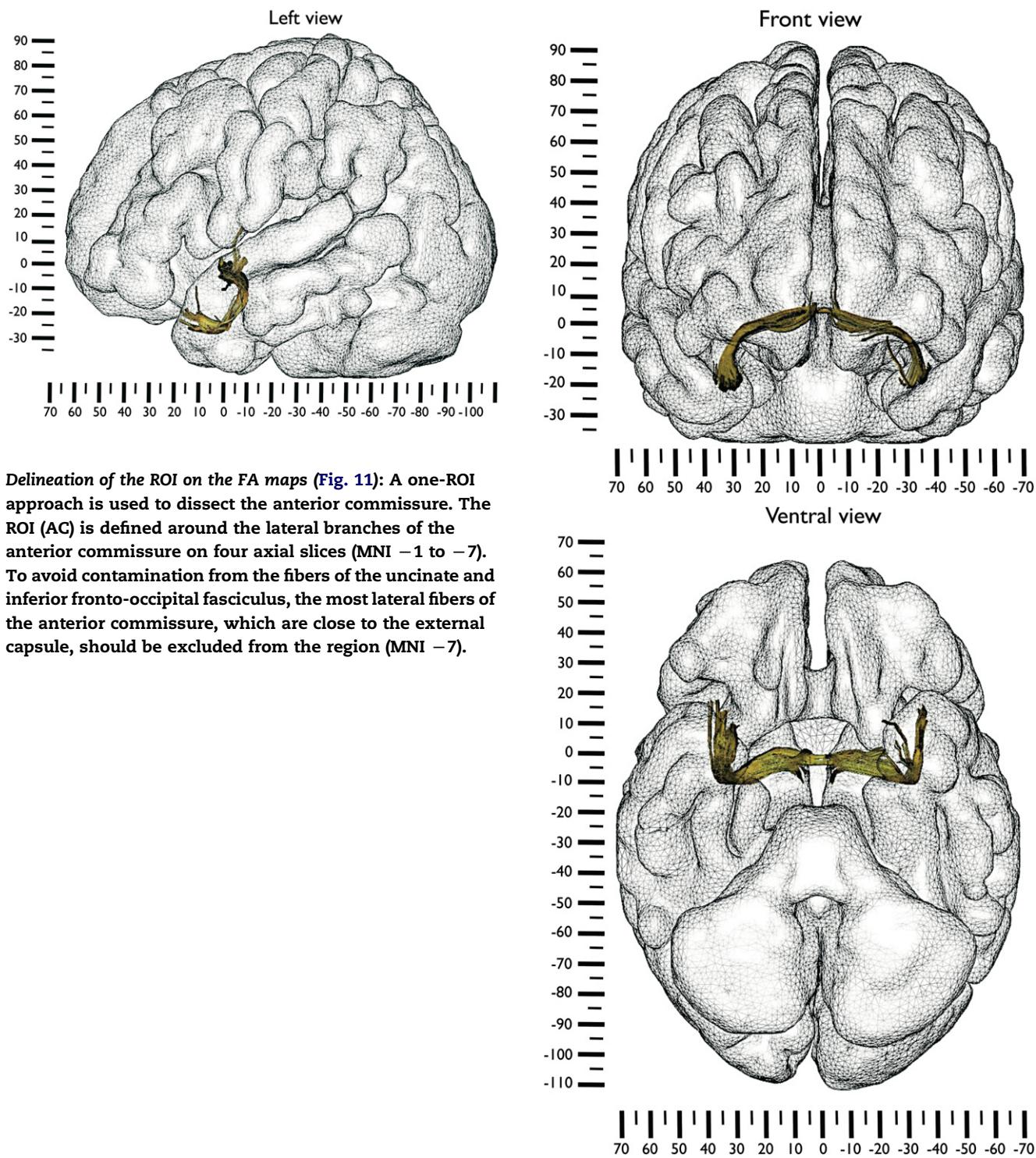


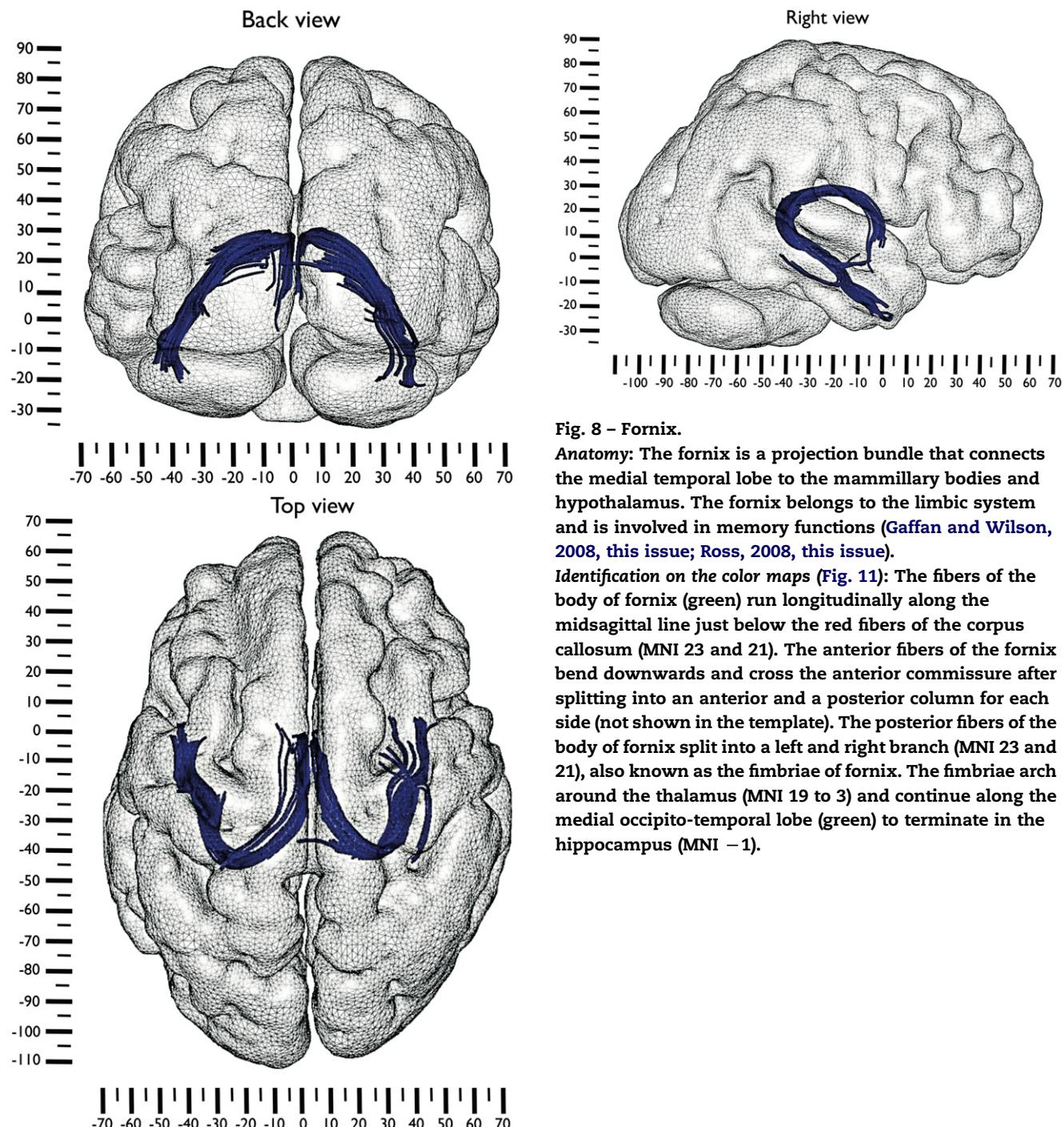


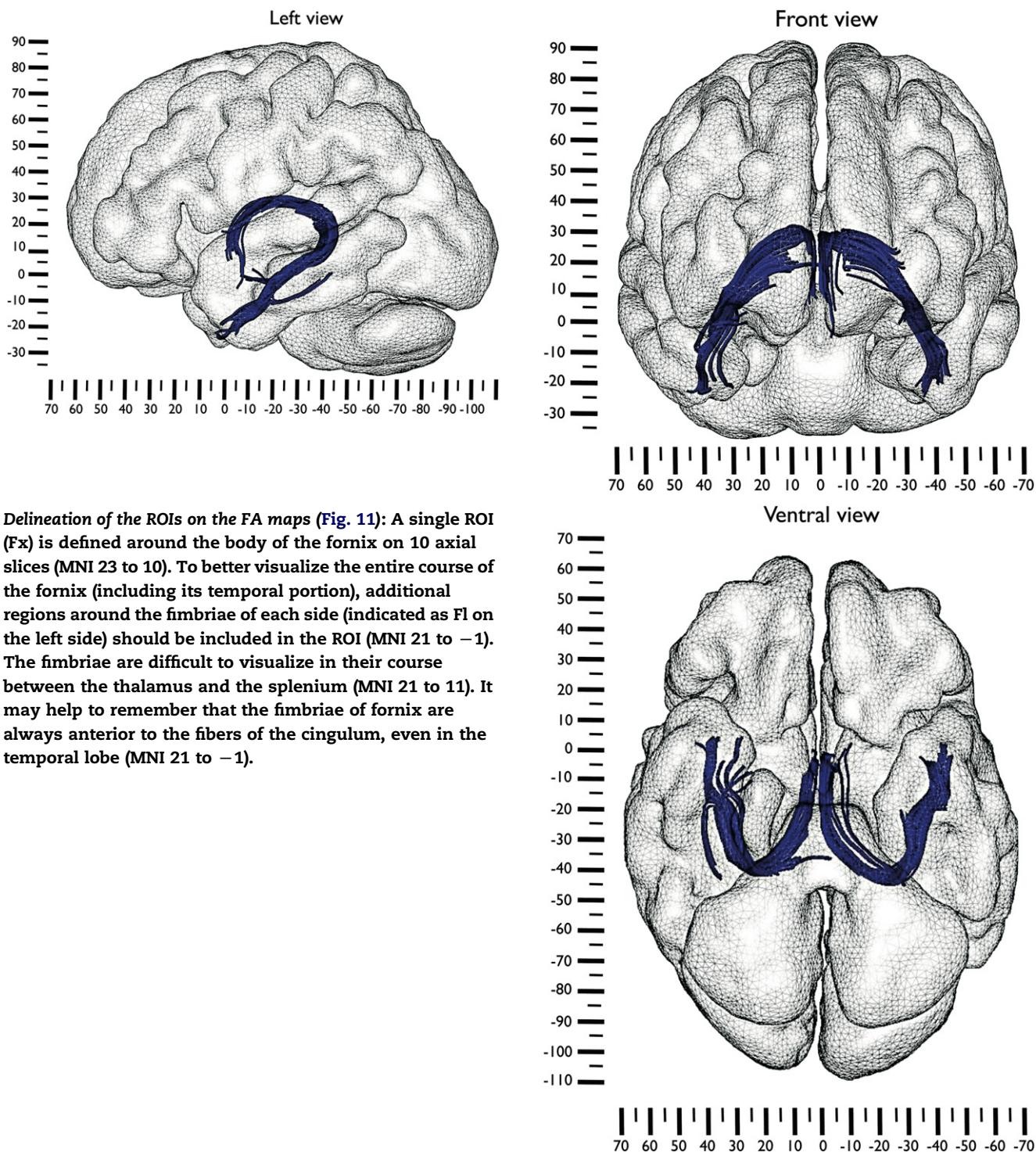
**Fig. 7 – Anterior commissure.**

**Anatomy:** The anterior commissure connects the anterior and ventral temporal lobes (including the amygdala) of the two hemispheres. The functions of the anterior commissure are poorly understood (Glickstein and Berlucchi, 2008, *this issue*; Catani et al., 2002).

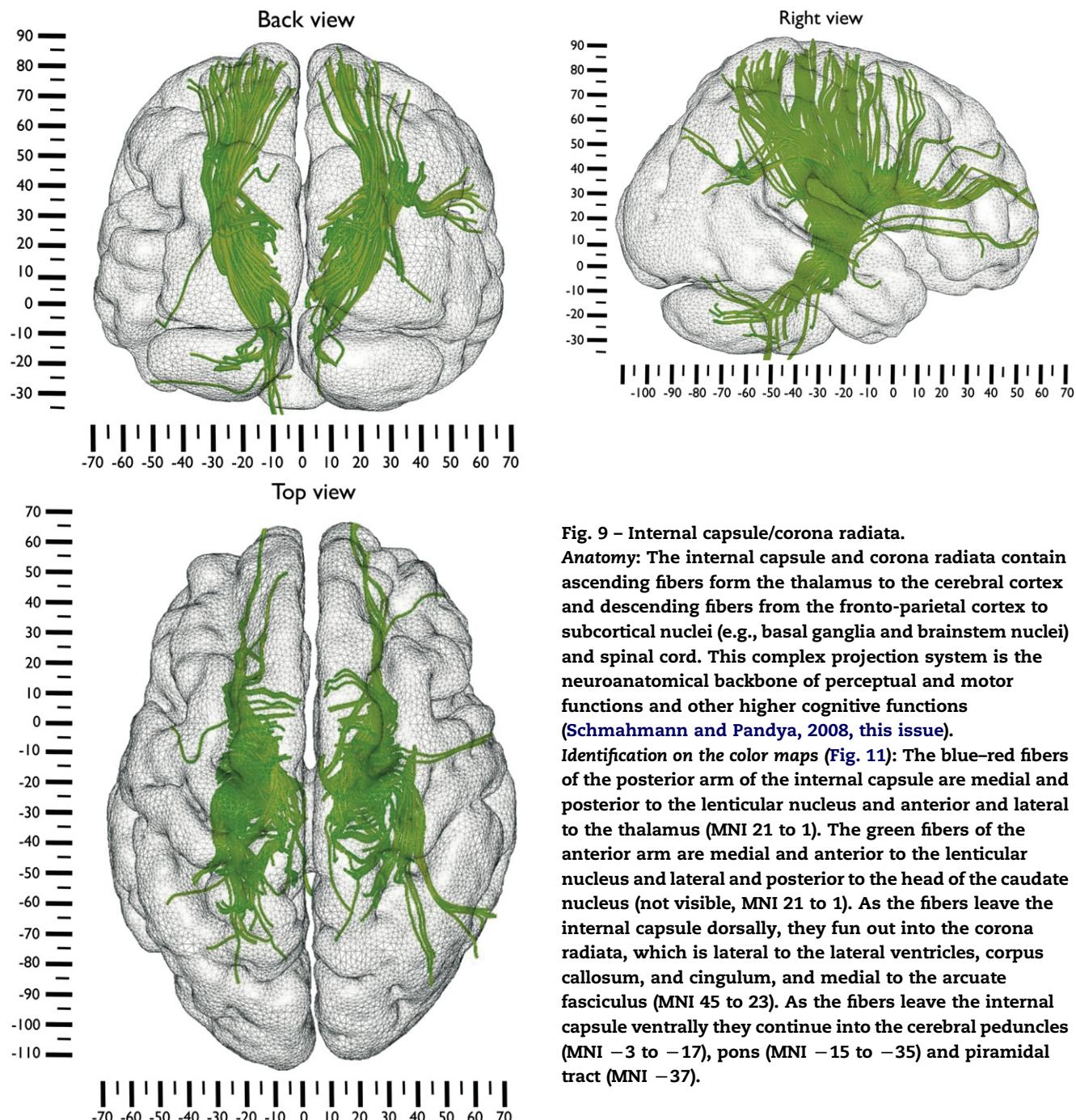
**Identification on the color maps (Fig. 11):** The fibers of the anterior commissure (red) are medial to the fibers of the external/extreme capsule (green), ventral to the most anterior part of the body of fornix, and anterior to the cerebral peduncles (MNI –1 to –7).







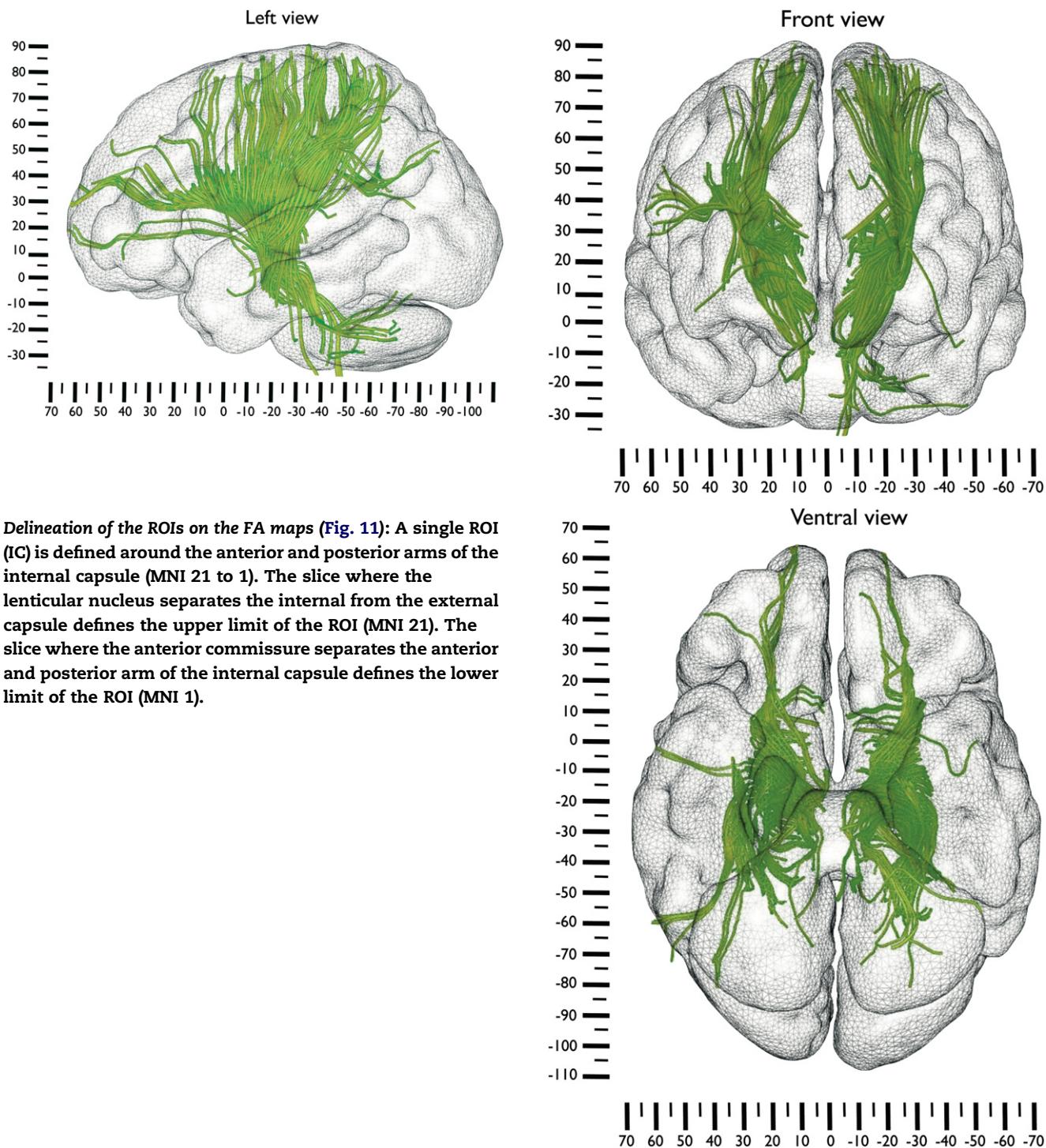
**Delineation of the ROIs on the FA maps (Fig. 11):** A single ROI (Fx) is defined around the body of the fornix on 10 axial slices (MNI 23 to 10). To better visualize the entire course of the fornix (including its temporal portion), additional regions around the fimbriae of each side (indicated as Fl on the left side) should be included in the ROI (MNI 21 to –1). The fimbriae are difficult to visualize in their course between the thalamus and the splenium (MNI 21 to 11). It may help to remember that the fimbriae of fornix are always anterior to the fibers of the cingulum, even in the temporal lobe (MNI 21 to –1).

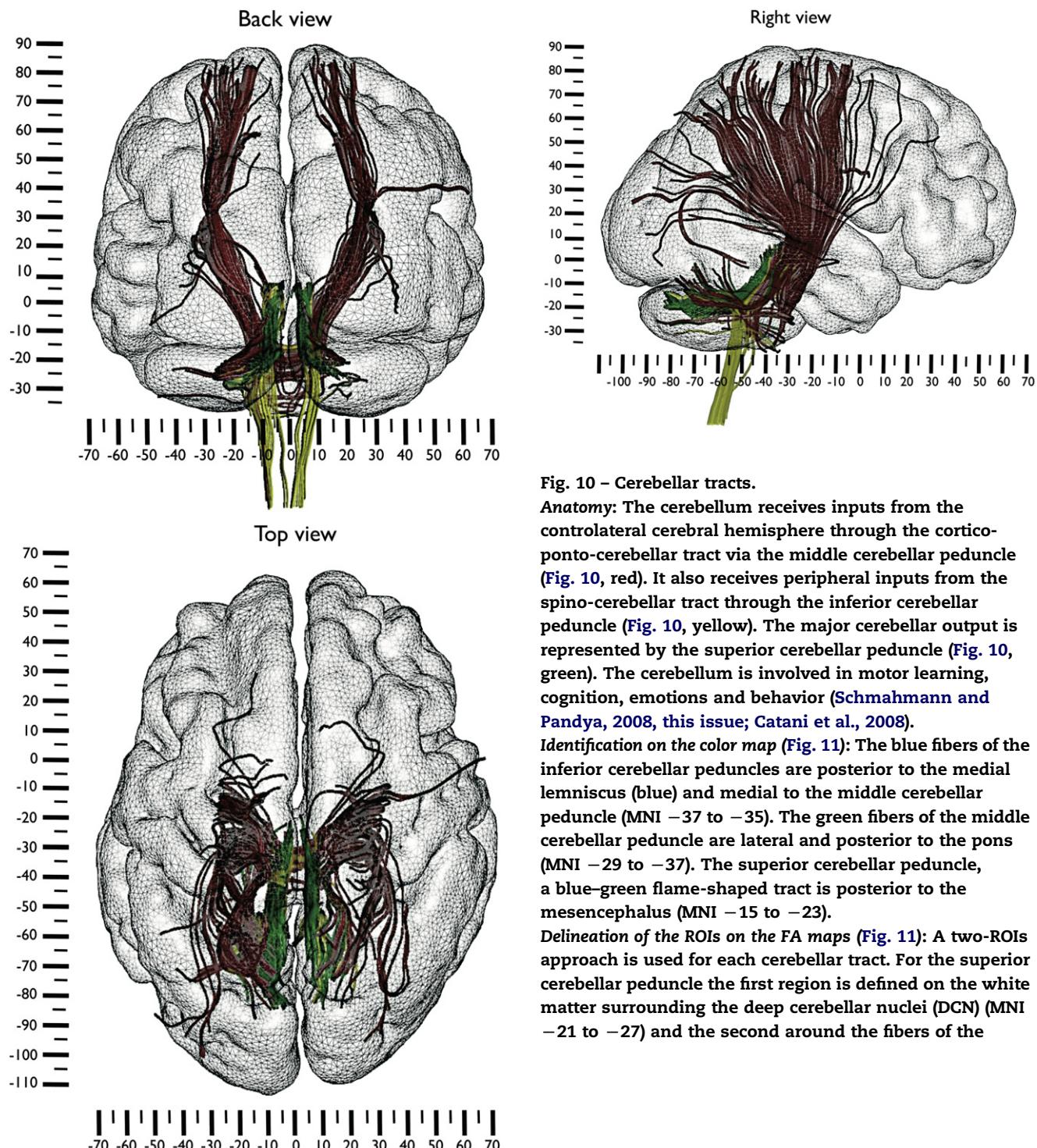


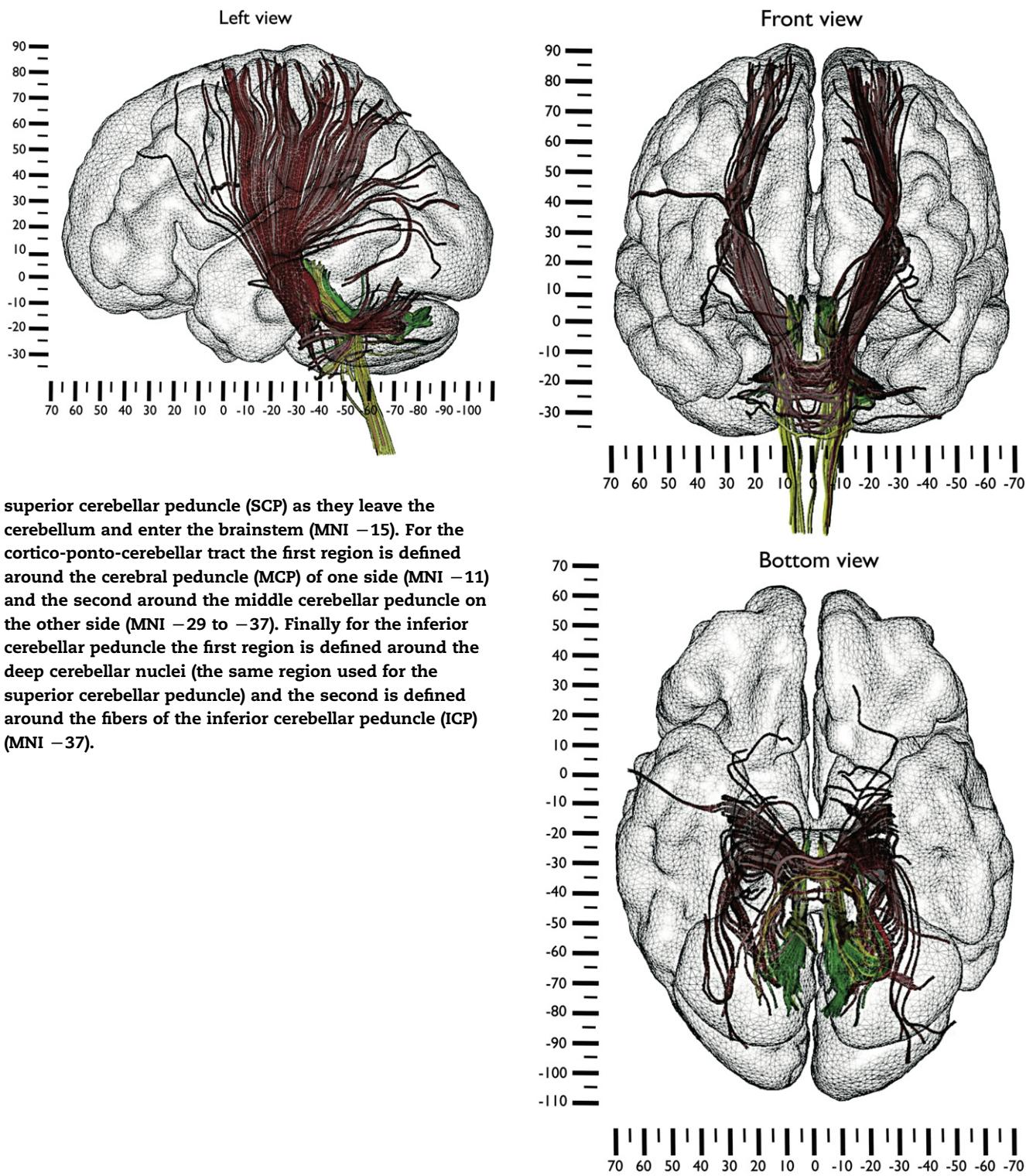
**Fig. 9 – Internal capsule/corona radiata.**

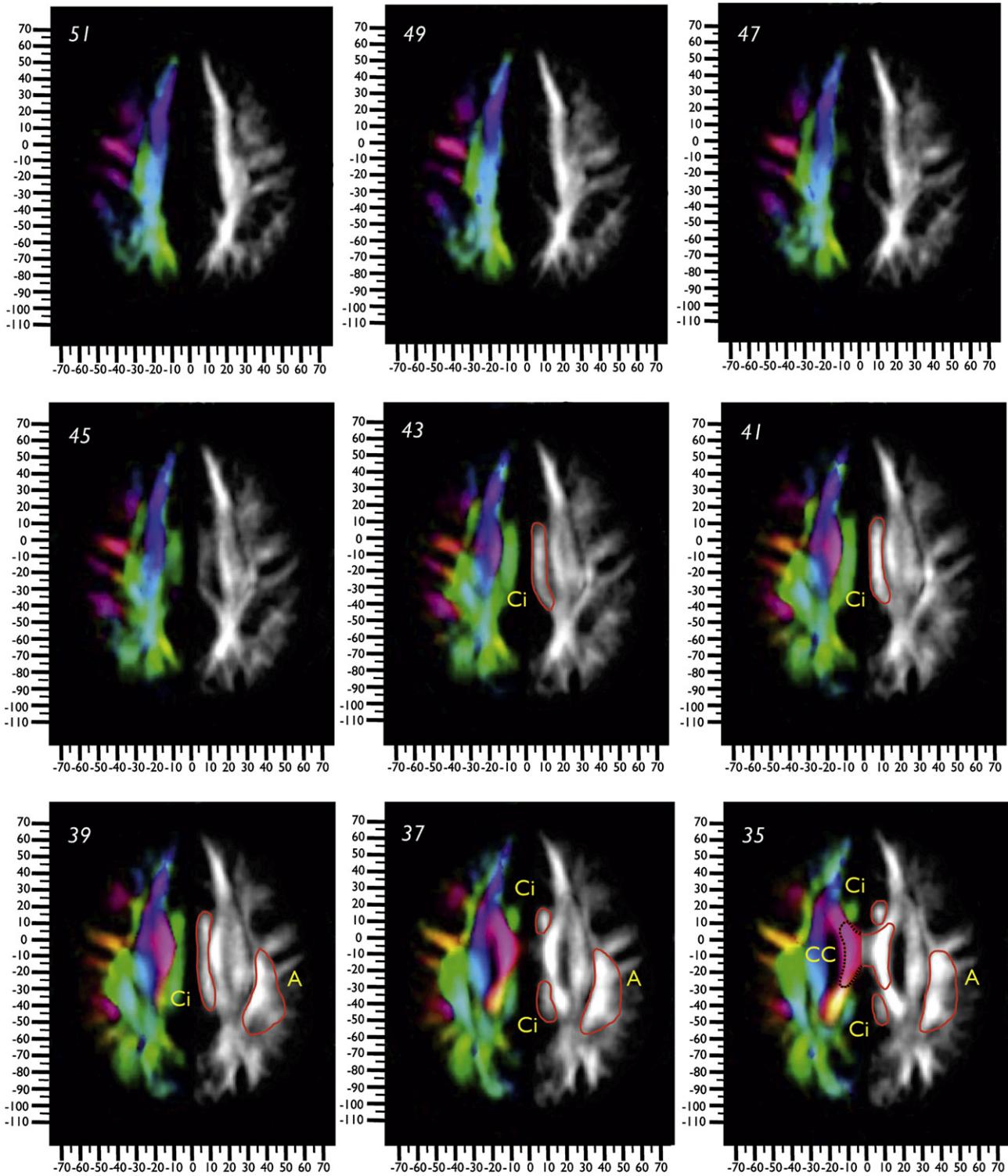
**Anatomy:** The internal capsule and corona radiata contain ascending fibers from the thalamus to the cerebral cortex and descending fibers from the fronto-parietal cortex to subcortical nuclei (e.g., basal ganglia and brainstem nuclei) and spinal cord. This complex projection system is the neuroanatomical backbone of perceptual and motor functions and other higher cognitive functions (Schmahmann and Pandya, 2008, this issue).

**Identification on the color maps (Fig. 11):** The blue-red fibers of the posterior arm of the internal capsule are medial and posterior to the lenticular nucleus and anterior and lateral to the thalamus (MNI 21 to 1). The green fibers of the anterior arm are medial and anterior to the lenticular nucleus and lateral and posterior to the head of the caudate nucleus (not visible, MNI 21 to 1). As the fibers leave the internal capsule dorsally, they fan out into the corona radiata, which is lateral to the lateral ventricles, corpus callosum, and cingulum, and medial to the arcuate fasciculus (MNI 45 to 23). As the fibers leave the internal capsule ventrally they continue into the cerebral peduncles (MNI -3 to -17), pons (MNI -15 to -35) and pyramidal tract (MNI -37).









#### ROIs legend

A	Arcuate	Fx	Fornix body	SCP	Superior cerebellar peduncle
AC	Anterior Commissure	Fl	Fimbriae of fornix left	MCP	Middle cerebellar peduncle
CC	Corpus Callosum	T	Temporal	ICP	Inferior cerebellar peduncle
Ci	Cingulum	O	Occipital	DCN	Deep cerebellar nuclei
CP	Cerebral peduncle	IC	Internal capsule		
E	External/Extreme capsule				

**Fig. 11 – Diffusion tensor image template of an average data set and delineation of ROIs.** The FA maps on the right provide information about the general anatomy of the major association, commissural and projection white matter tracts. The color maps on the left provide additional information on the local orientation of the tracts, where red color indicates a latero-lateral direction (left to right and right to left), green color an anterior-posterior direction (and vice versa), and blue color a dorsal-ventral direction (and vice versa). Other colors indicate intermediate directions.

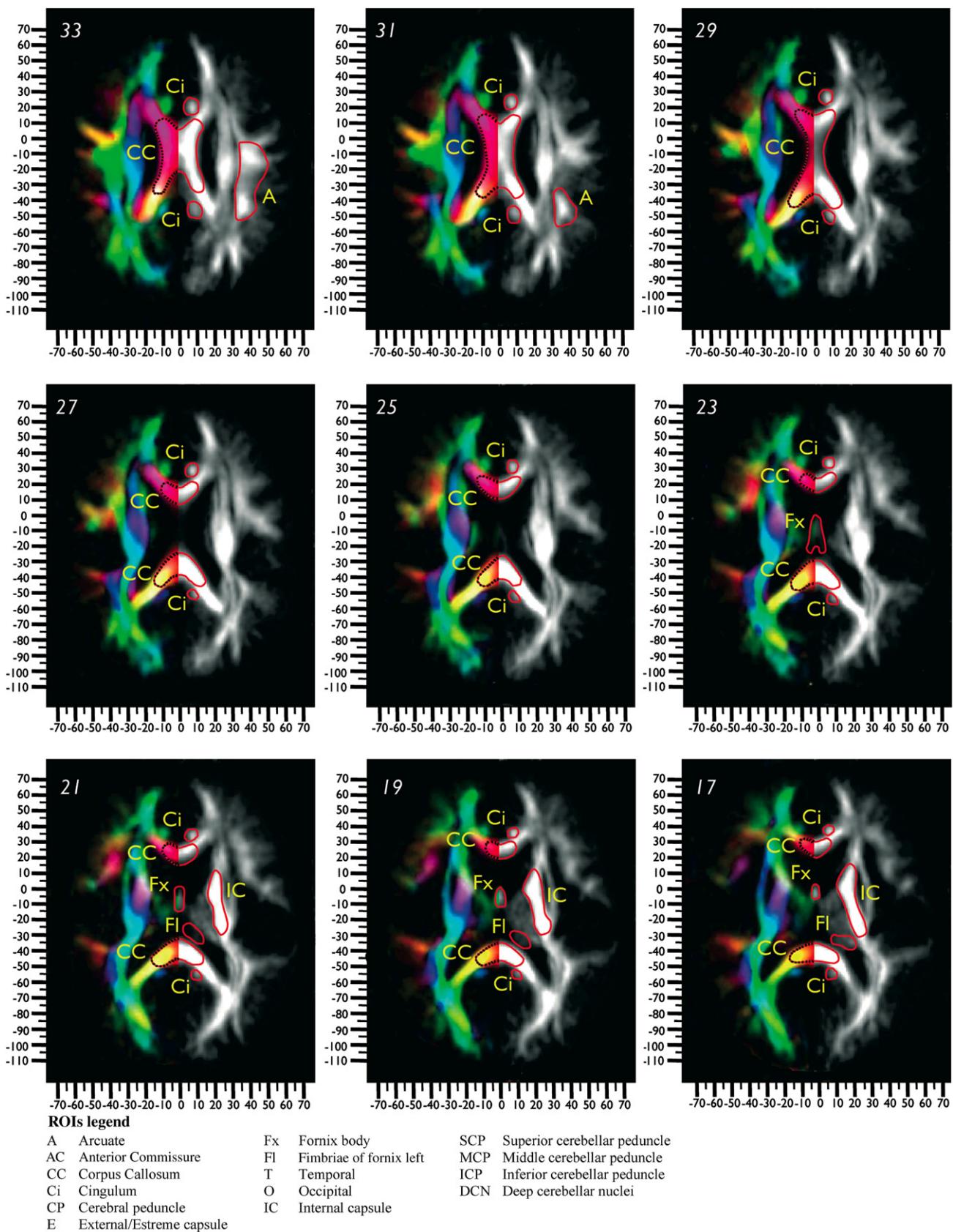
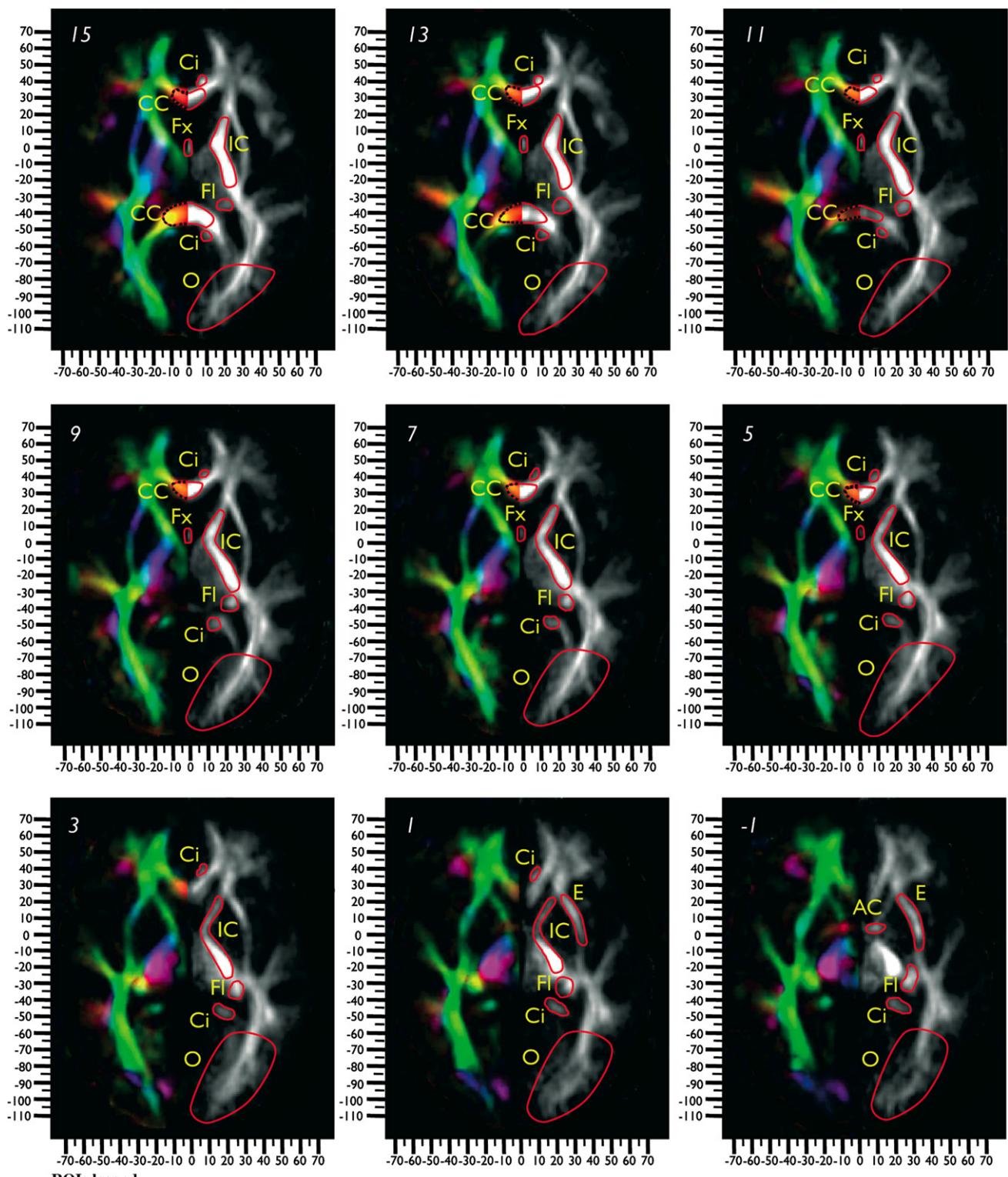


Fig. 11 – Continued

**ROIs legend**

A	Arcuate	Fx	Fornix body	SCP	Superior cerebellar peduncle
AC	Anterior Commissure	Fl	Fimbriae of fornix left	MCP	Middle cerebellar peduncle
CC	Corpus Callosum	T	Temporal	ICP	Inferior cerebellar peduncle
Ci	Cingulum	O	Occipital	DCN	Deep cerebellar nuclei
CP	Cerebral peduncle	IC	Internal capsule		
E	External/Extreme capsule				

**Fig. 11 – Continued**

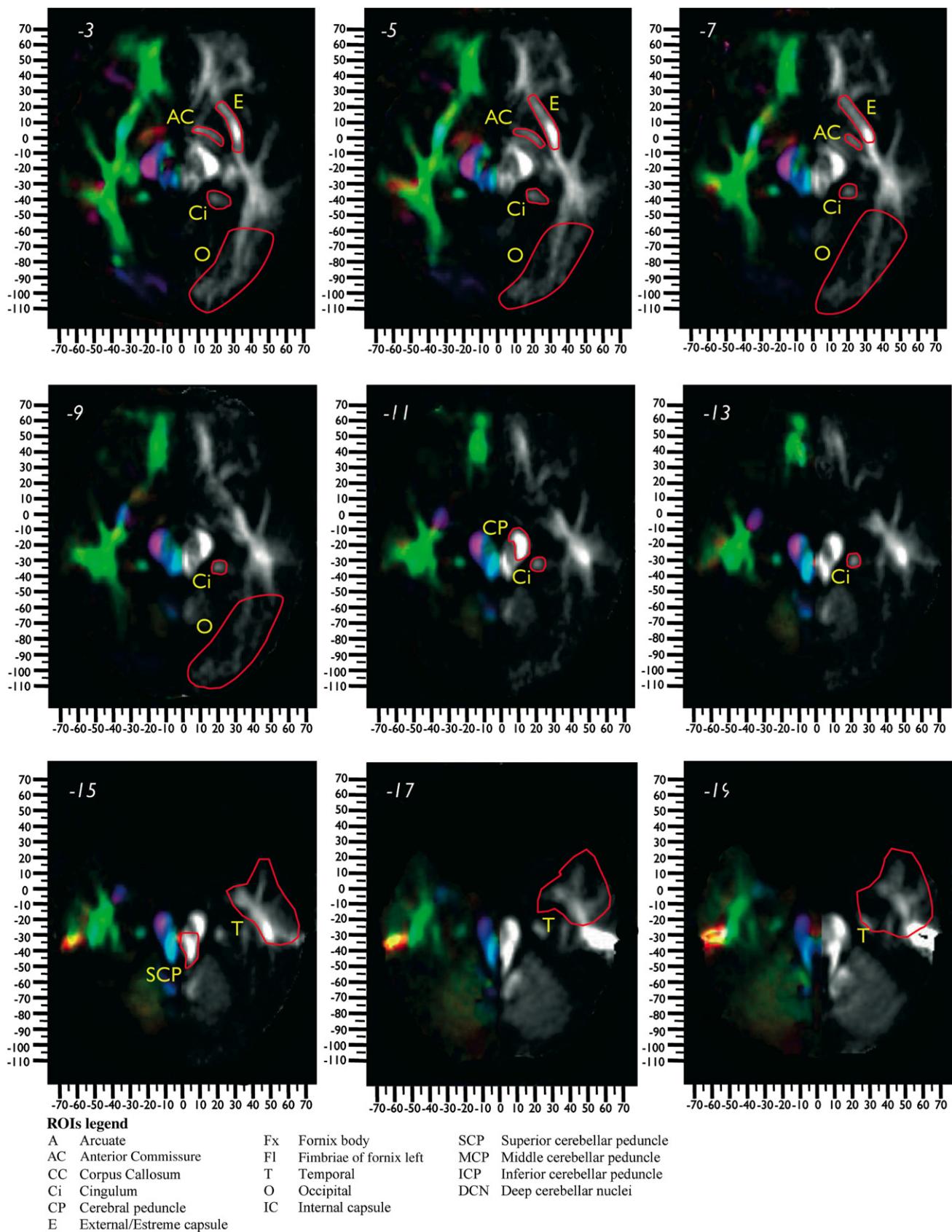


Fig. 11 – Continued

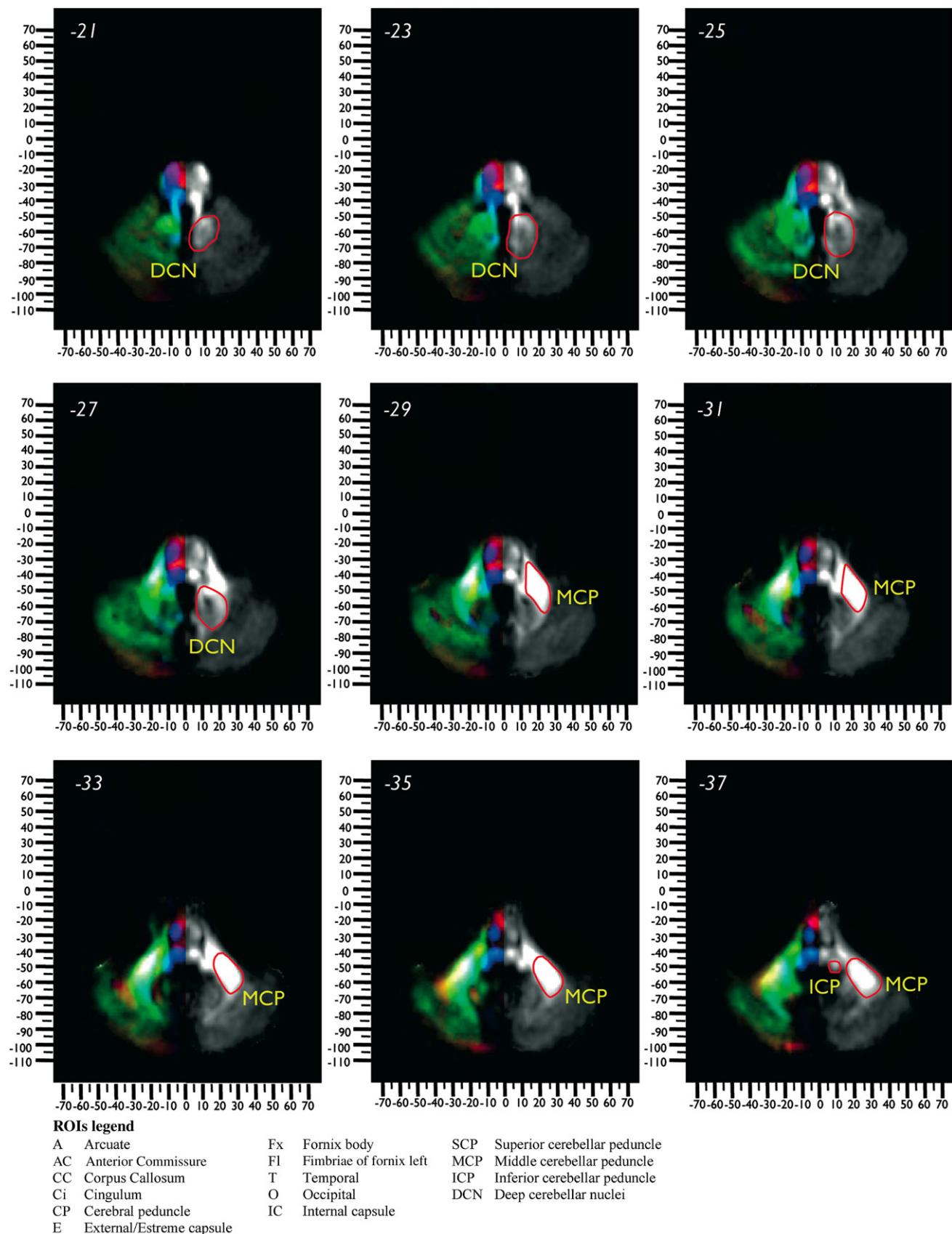


Fig. 11 – Continued

of this second approach is that the method requires a priori anatomical knowledge to identify the course of white matter pathways and delineate ROIs on DTI images. Here, we provide a tool to teach tractography-derived white matter anatomy and to perform virtual *in vivo* dissections of the major tracts of the human brain. First, we have created a 3D tractography atlas of the associative, commissural and projection pathways in a standardized system of coordinates (Montreal Neurological Institute, MNI space) (Figs. 1–10). The atlas, together with the description of each tract in the figure legends, can be used as anatomical reference. Second, we provide some guidelines for the identification of the pathways in the color maps and show how to delineate ROIs on axial fractional anisotropy (FA) images from an average data set (Fig. 11). We hope that the atlas and the template for ROIs will be used as a tool for teaching and guiding virtual brain dissections in single cases and case-control studies.

## 2. Methods

### 2.1. DTI data set acquisition, processing, and averaging

Twelve right-handed male subjects ( $34.3 \pm 5.7$  years old) gave written consent to participate in the study, which was approved by the local ethics committee at the Service Hospitalier Frédéric Joliot, Orsay. MRI data were acquired using echo-planar imaging at 1.5 T (General Electric Healthcare Signa) with a standard head coil for signal reception. High resolution T1-weighted anatomical images were acquired (gradient-echo sequence, repetition time 9.9 ms, echo time 2 ms, matrix  $256 \times 192$ , field of view 24 cm, slice thickness 1.2 mm). DTI axial slices were obtained using the following parameters: repetition time 19 s; echo time 93 ms; flip angle 90°; voxel size  $1.88 \times 1.88 \times 2$  mm, 200 independent directions, *b*-value  $3000\text{ s/mm}^2$ . Raw diffusion-weighted data were corrected for geometric distortion secondary to eddy currents using a registration technique based upon the geometric model of distortions (Mangin et al., 2002). Two representative data sets were used to perform virtual dissections and create a 3D atlas of the major white matter tracts in the MNI space (Fig. 1–10). The 12 data sets were spatially normalized and averaged using a method similar to the method previously described by Jones et al. (2002). Briefly, the method includes the following steps: (i) registration of individual T1 images with the diffusion tensor data sets; (ii) normalization of the registered T1 using both linear and non-linear parameters; (iii) normalization of the diffusion tensor data sets using the deformation parameters derived from (ii); (iv) averaging of the normalized diffusion tensor data set. For the registration we used BRAINVISA 3.0.2 (<http://brainvisa.info>), which allows re-orientation of each tensor correctly along the AC/PC plan. For the normalization we used statistical parametric mapping software (SPM5, Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK, <http://www.fil.ion.ucl.ac.uk/>) and MATLAB version 7 (The Mathworks, Inc., MA, USA). Images were spatially normalized to the standard T1 template provided in SPM5. The 3D tractography reconstructions of each tract were registered in the

MNI space and visualized within a glass brain using BRAINVISA 3.0.2.

### 2.2. DTI template for the delineation of the ROIs

We combined color and FA diffusion tensor images to create a split-half template from an average data set. The axial diffusion images are presented in Fig. 11. The FA maps of the right hemisphere provide information about the general anatomy of the principal white matter tracts. The color maps of the left hemisphere provide additional information on the local orientation of the tracts, where red color indicates a latero-lateral direction (left to right and right to left), green color an anterior-posterior direction (and vice versa), and blue color a dorsal-ventral direction (and vice versa). Other colors indicate intermediate orientations. ROIs are defined on the axial FA images and were used as starting regions for tracking. Unlike other methods that use cortical masks as starting regions, the approach adopted here defines ROIs around areas of white matter that represent “obligatory passages” along the course of each tract. These obligatory passages represent brain regions that all fibres of each tract must pass through in order to reach their cortical or subcortical endstations (Catani et al., 2002). Hence, the use of obligatory passages as starting seed points for tracking allows to visualize all fibers of a single tract without constraining its cortical projections, which may vary from subject to subject. For example, all projection fibers from the thalamus to the cerebral hemisphere or from the cerebral hemisphere to spinal cord pass through the internal capsule to reach their endstations; hence the internal capsule represents the obligatory passage for this thalamo-cortico and cortico-spinal projection system. If the ROI representing an obligatory passage contains only fibres of the tract of interest, a single (one) ROI approach is used (i.e., all fibres passing through the ROI are displayed and considered as belonging to a single tract). A one-ROI approach is used for the arcuate fasciculus, cingulum, corpus callosum, anterior commissure and fornix. Other tracts share their obligatory passages with one or more tracts. In this case a two-ROIs approach is used where a second ROI is defined, such that it contains at least a section of the desired fasciculus but does not contain any fibers of the undesired fasciculi that pass through the first ROI (Conturo et al., 1999). Two-ROIs approach is used for the cerebellar tracts and the uncinate, inferior longitudinal and inferior fronto-occipito fasciculi. A second ROI can also be used to exclude undesired streamlines (i.e., display all fibers passing though the first ROI but not the second ROI). The inter-subjects reliability of this method was calculated among 10 operators in relation to an experienced tractographer (MC). All operators dissected ten tracts from a single dataset and measured diffusivity indexes from the dissected tracts. Pearson’s correlation between each operator and the expert tractographer was calculated. A high inter-subject reliability was found for the volume of the ROIs (mean  $r=.998$ ,  $SD=.001$ ), number of streamlines (mean  $r=.998$ ,  $SD=.001$ ), volume of the tracts (mean  $r=.998$ ,  $SD=.0009$ ), length of the tracts (mean  $r=.994$ ,  $SD=.008$ ) and tract-specific FA measurements (mean  $r=.958$ ,  $SD=.053$ ).

## Acknowledgements

We would like to thank Cyril Poupon for the MRI diffusion database. The database is the property of CEA SHFJ/UNAF and can be provided on demand to [coupon@shfj.cea.fr](mailto:coupon@shfj.cea.fr). Data were post-processed with AIMS/Anatomist/BrainVisa software, freely available at <http://brainvisa.info>.

We also would like to thank Flavio Dell'acqua and Luca Pugliese from the NATBRAINLAB (<http://www.natbrainlab.com>) for the helpful discussion. This project was generously supported by the Medical Research Council (UK) A.I.M.S. network and the South London and Maudsley NHS Trust (National Division), London, England.

## REFERENCES

- Basser PJ, Pajevic S, Pierpaoli C, Duda J, and Aldroubi A. In vivo fiber tractography using DT-MRI data. *Magnetic Resonance in Medicine*, 44: 625–632, 2000.
- Balsamo M, Trojano L, Giamundo A, and Grossi D. Left hand tactile agnosia after posterior callosal lesion. *Cortex*, 44: 1030–1036, 2008.
- Catani M. Diffusion tensor magnetic resonance imaging tractography in cognitive disorders. *Current Opinion in Neurology*, 19: 599–606, 2006.
- Catani M. From hodology to function. *Brain*, 130: 602–605, 2007.
- Catani M, Jones DK, Donato R, and ffytche DH. Occipito-temporal connections in the human brain. *Brain*, 126: 2093–2107, 2003.
- Catani M, Jones DK, and ffytche DH. Perisylvian language networks of the human brain. *Annals of Neurology*, 57: 8–16, 2005.
- Catani M, Allin M, Husain M, Pugliese L, Mesulam M, Murray R, et al. Symmetries in human brain language pathways predict verbal recall. *Proceedings of the National Academy of Sciences of the United States of America*, 104: 17163–17168, 2007.
- Catani M, Jones D, Daly E, Deeley Q, Embiricos N, Pugliese L, et al. Altered cerebellar feedback projections in Asperger syndrome. *Neuroimage*, 41: 1184–1191, 2008.
- Catani M, Howard RJ, Pajevic S, and Jones DK. Virtual in vivo interactive dissection of white matter fasciculi in the human brain. *Neuroimage*, 17: 77–94, 2002.
- Concha L, Beaulieu C, and Gross DW. Bilateral limbic diffusion abnormalities in unilateral temporal lobe epilepsy. *Annals of Neurology*, 57: 188–196, 2005.
- Conturo TE, Lori NF, Cull TS, Akbudak E, Snyder AZ, Shimony JS, et al. Tracking neuronal fiber pathways in the living human brain. *Proceedings of the National Academy of Sciences of the United States of America*, 96: 10422–10427, 1999.
- Catani M and Mesulam M. What is a disconnection syndrome? *Cortex*, 44: 911–913, 2008a.
- Catani M and Mesulam M. The arcuate fasciculus and the disconnection theme in language and aphasia: history and current state. *Cortex*, 44: 953–961, 2008b.
- Doricchi F, de Thiebaut de Schotten M, Tomaiuolo F, and Bartolomeo P. White matter (dis)connections and gray matter (dys)functions in visual neglect: Gaining insights into the brain networks of spatial awareness. *Cortex*, 44: 983–995, 2008.
- Doron KW and Gazzaniga MS. Neuroimaging techniques offer new perspectives on callosal transfer and interhemispheric communication. *Cortex*, 44: 1023–1029, 2008.
- Epelbaum S, Pinel P, Gaillard R, Delmaire C, Perrin M, and Dupont S, et al. Pure alexia as a disconnection syndrome: New diffusion imaging evidence for an old concept. *Cortex*, 44: 962–974, 2008.
- Fox CJ, Iaria G, and Barton JJS. Disconnection in prosopagnosia and face processing. *Cortex*, 44: 996–1009, 2008.
- ffytche DH. The hodology of hallucinations. *Cortex*, 44: 1067–1083, 2008.
- ffytche DH and Catani M. Beyond localization: from hodology to function. *Philosophical Transactions of the Royal Society of London B Biological Sciences*, 360: 767–779, 2005.
- Gaffan D and Wilson CRE. Medial temporal and prefrontal function: Recent behavioural disconnection studies in the macaque monkey. *Cortex*, 44: 928–935, 2008.
- Glickstein M and Berlucchi G. Classical disconnection studies of the corpus callosum. *Cortex*, 44: 914–927, 2008.
- Heilmann KM and Watson RT. Disconnectional apraxia. *Cortex*, 44: 975–982, 2008.
- Jones DK. Determining and visualizing uncertainty in estimates of fiber orientation from diffusion tensor MRI. *Magnetic Resonance in Medicine*, 49: 7–12, 2003.
- Jones DK. Studying connections in the living human brain with diffusion MRI. *Cortex*, 44: 936–952, 2008.
- Jones DK, Griffin LD, Alexander DC, Catani M, Horsfield MA, Howard R, et al. Spatial normalization and averaging of diffusion tensor MRI data sets. *Neuroimage*, 17: 592–617, 2002.
- Lawes IN, Barrick TR, Murugam V, Spierings N, Evans DR, Song M, et al. Atlas-based segmentation of white matter tracts of the human brain using diffusion tensor tractography and comparison with classical dissection. *Neuroimage*, 39: 62–79, 2008.
- Mangin JF, Poupon C, Clark C, Le Bihan D, and Bloch I. Distortion correction and robust tensor estimation for MR diffusion imaging. *Med Image Anal*, 6: 191–198, 2002.
- Mori S, Kaufmann WE, Pearlson GD, Crain BJ, Stieltjes B, Solaiyappan M, et al. In vivo visualization of human neural pathways by magnetic resonance imaging. *Annals of Neurology*, 47: 412–414, 2000.
- Rudrauf D, Mehta S, and Grabowski T. Disconnection's renaissance takes shape: Formal incorporation in group-level lesion studies. *Cortex*, 44: 1084–1096, 2008.
- Ross ED. Sensory-specific amnesia and hypoemotionality in humans and monkeys: Gateway for developing a hodology of memory. *Cortex*, 44: 1010–1022, 2008.
- Schmahmann J and Pandya DN. Disconnection syndromes of basal ganglia, thalamus, and cerebrocerebellar systems. *Cortex*, 44: 1037–1066, 2008.
- Thiebaut de Schotten M, Kinkingnéhun S, Delmaire C, Lehéricy S, Duffau H, and Thivard L, et al. Visualization of disconnection syndromes in humans. *Cortex*, 44: 1097–1103, 2008.