

# Supplementary Data

## Neurite imaging reveals microstructural variations in human cerebral cortical gray matter

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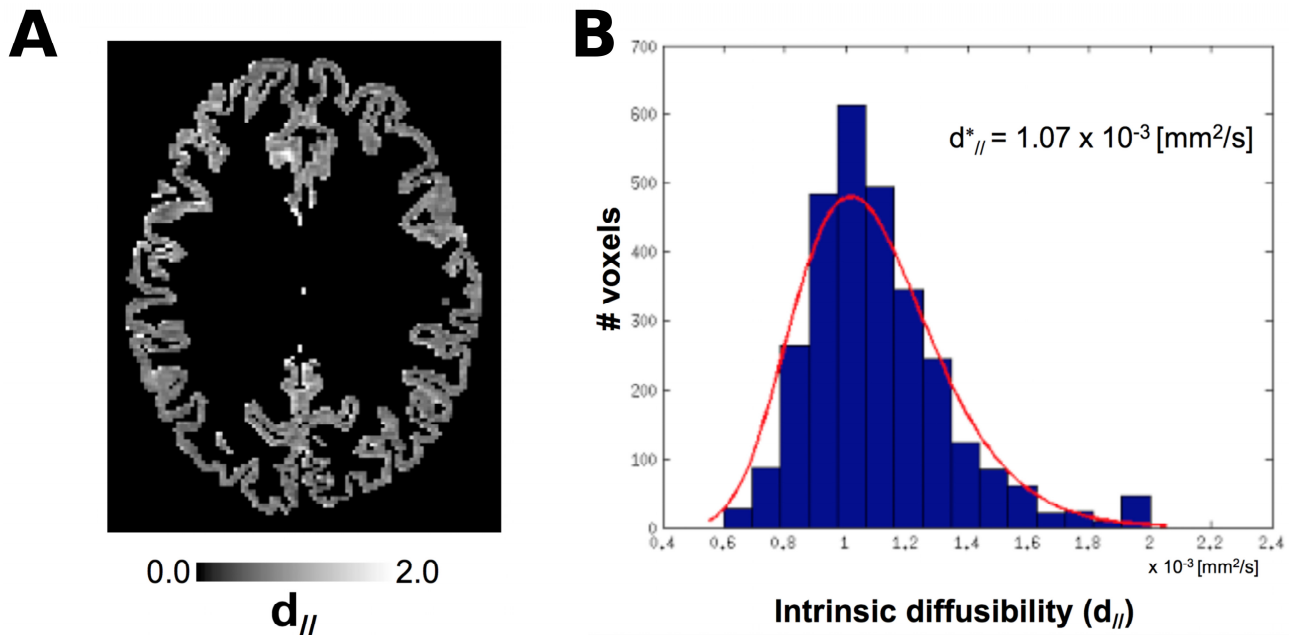
## Supplementary Tables

**Table S1.** Correlation matrix of cortical surface measures.

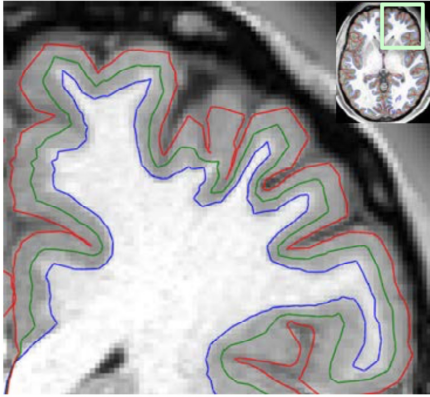
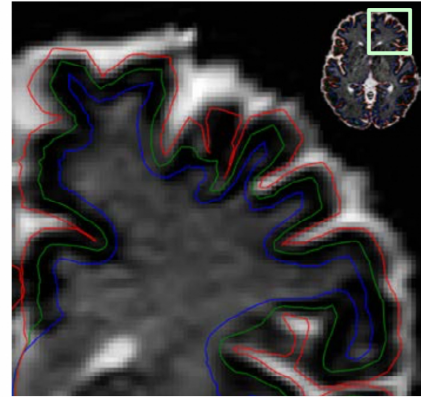
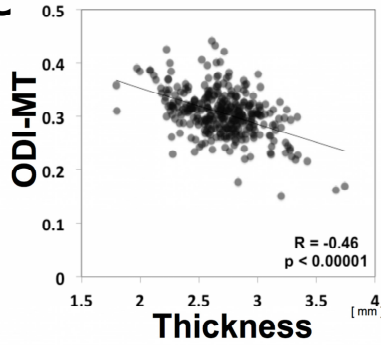
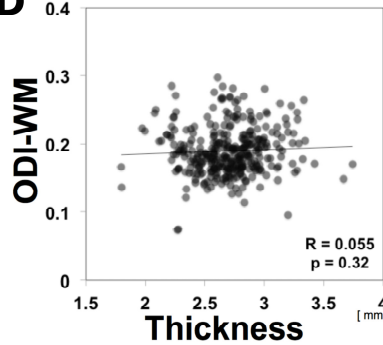
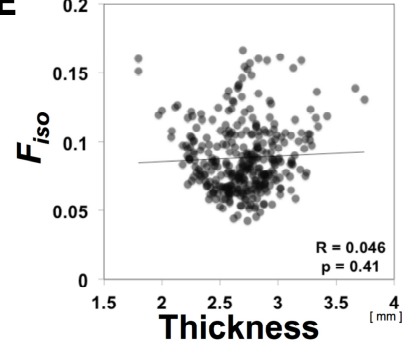
	NDI	ODI	Myelin	Thickness	FA (bAll)	MD (bAll)	FA (b1000)	MD (b1000)
NDI	—	0.40***	0.60***	−0.15	0.27***	−0.91***	0.27***	−0.20*
ODI	0.60***	—	0.44***	−0.37***	−0.69***	−0.40***	−0.70***	−0.22*
Myelin	0.68***	0.62***	—	−0.46***	0.054	−0.60***	−0.10	−0.37***
Thickness	−0.18*	−0.46***	−0.53***	—	0.20*	0.17	0.41***	0.22*
FA (bAll)	0.28***	−0.53***	0.10	0.20*	—	−0.22**	0.85***	−0.091
MD (bAll)	−0.97***	−0.63***	−0.69***	0.20*	−0.26***	—	−0.26***	0.48***
FA (b1000)	0.28***	−0.55***	−0.16	0.50***	0.82***	−0.20*	—	−0.00020
MD (b1000)	−0.31***	−0.42***	−0.47***	0.31***	−0.071	0.53***	0.22**	—

Correlation coefficients based on group-averaged cortical maps are shown below the diagonal, whereas the mean correlation coefficients across subjects are shown above the diagonal. FA(bAll) and MD (bAll) were calculated using all the diffusion data including  $b=1000$ ,  $2000$  and  $3000$   $\text{s/mm}^2$ , while FA(b1000) and MD (b1000) using diffusion data of  $b=1000$   $\text{s/mm}^2$ (see main text). \*\*\*  $p<0.00001$ ; \*\*  $p<0.0001$ ; \*  $p<0.001$ .

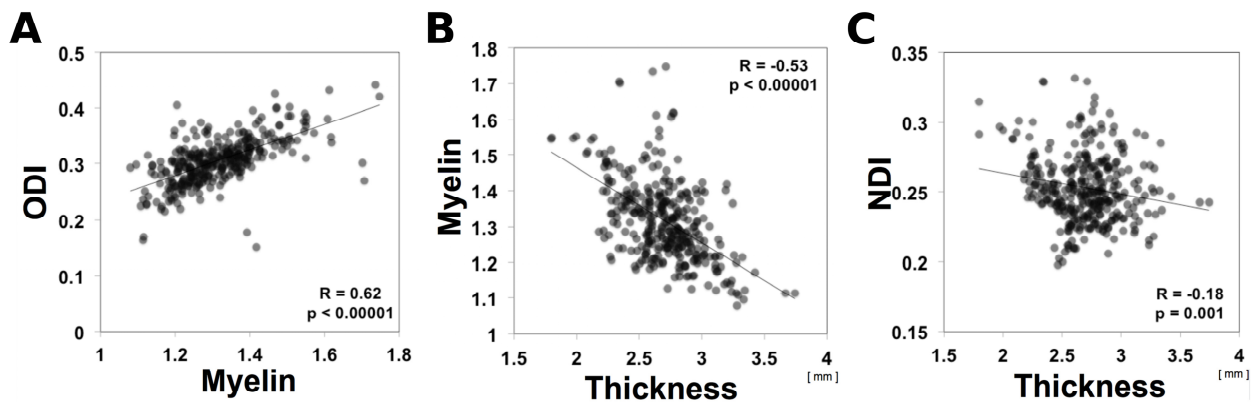
## Supplementary Figures and Figure Legends



**Supplementary Figure S1.** Determination of the gray matter intrinsic diffusion coefficient ( $d_{//}$ ). **(A)**  $d_{//}$  map for a middle axial slice. **(B)** Histogram displays cortical  $d_{//}$  distribution and the red line indicates maximum likelihood estimation using log-normal distribution. The maximum likelihood  $d_{//}$  ( $d_{//}^*$ ) value in this subject is  $1.07 \times 10^{-3} \text{ mm}^2/\text{s}$ . Data at <https://balsa.wustl.edu/NzLX>

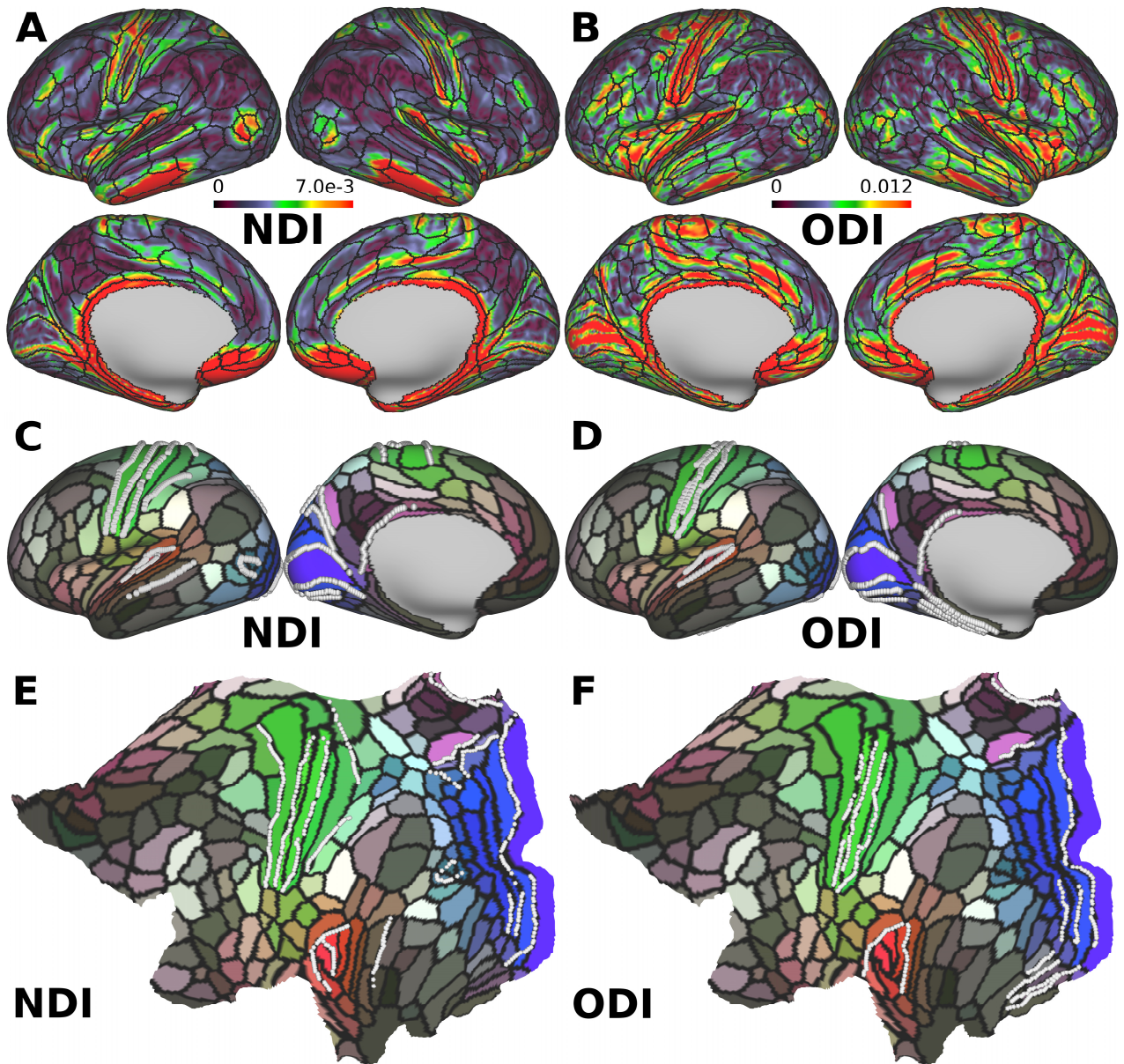
**A****T1w image****B****NODDI  $F_{iso}$** **C****D****E**

**Supplementary Figure S2.** Investigation of partial volume effect (PVE) in surface mapping of ODI. A) and B) show an individual subject's representative slice of T1-weighted images and cerebrospinal fluid (CSF) compartment of NODDI ( $F_{iso}$ ) with surface lines: the red line is the pial surface, the blue line is the white surface, and the green line is the mid-thickness surface. C), D) and E) show the correlation between group-averaged orientation dispersion index (ODI) mapped on the mid-thickness surface (ODI-MT), ODI mapped on the white matter surface (ODI-WM), and CSF compartment ( $F_{iso}$ ) mapped on the mid-thickness. Each data point represents the mean value for each of the 331 cortical parcels. The linear approximation indicates that the ODI-WM and CSF do not correlate with cortical thickness, whereas ODI-MT was correlated with thickness. Data at <https://balsa.wustl.edu/GzqM>



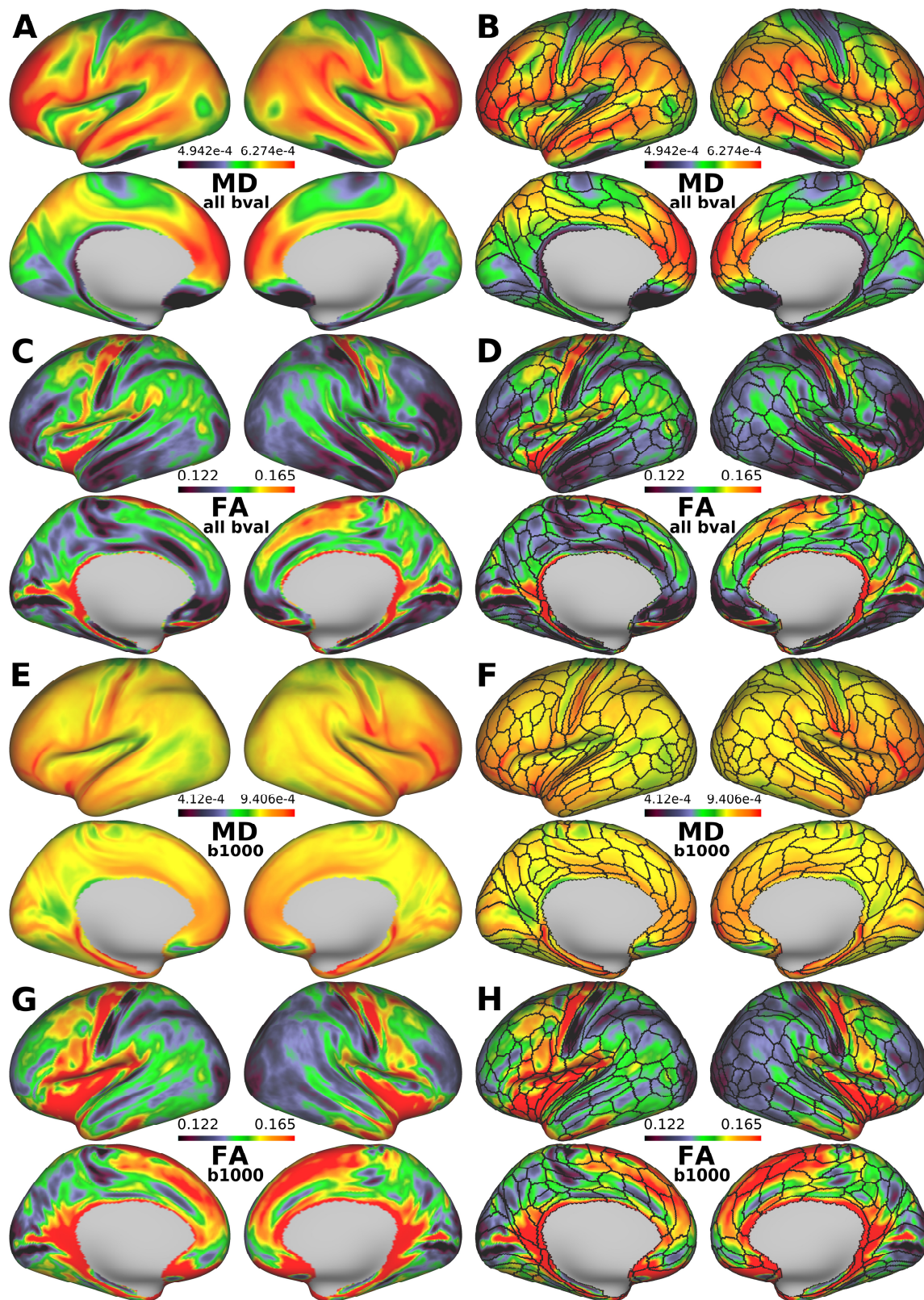
**Supplementary Figure S3.** Correlation between cortical architectural properties. **(A)** Orientation dispersion index (ODI) plotted against myelin. **(B)** Relative myelin content plotted against cortical thickness. **(C)** Neurite density index (NDI) plotted against cortical thickness. Each data point represents 505-subject mean value for each of the 331 parcels, where SNR is  $>17$ . The straight lines fitted to the data indicate that ODI content positively correlates with myelin content, relative myelin content negatively correlates with cortical thickness whereas NDI exhibits weak negative correlation with cortical thickness. Data at <https://balsa.wustl.edu/LzNP>



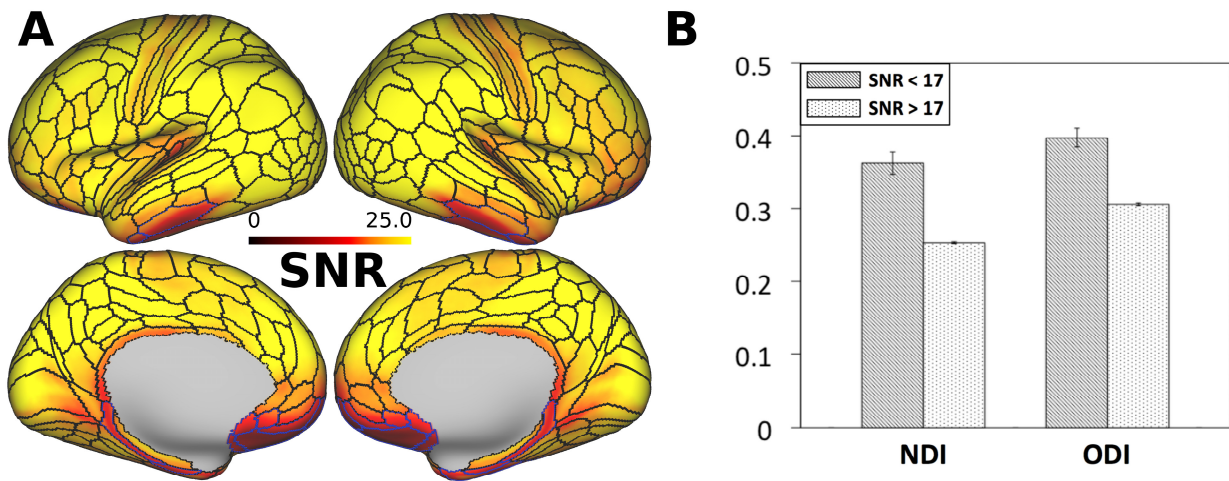


**Supplementary Figure S4.** Comparison of 505-subject mean gradient maps and borders of neurite density index (NDI) and orientation dispersion index (ODI) with the Human Connectome Project (HCP) parcellations of the cerebral cortex (Glasser et al., 2016). **(A)** The gradient of NDI exhibits in strong gradient changes in several but not all borders of cortical areas, indicating that neurite density varies between these cortical parcels. **(B)** The gradient of ODI shows less correspondence to the borders, and high gradients are found within some of parcellations, such as primary visual, motor, somatosensory areas. The borders estimated from gradient of NDI **(C,E, white dots)** correspond well to the HCP parcellations (color label and black borders) shown in inflated surface **(C)** and flat map **(E)**. The borders estimated from gradient of ODI **(D,F white dots)** show some correspondence with the HCP parcellations, but less than for NDI. Data at <https://balsa.wustl.edu/pvPi>



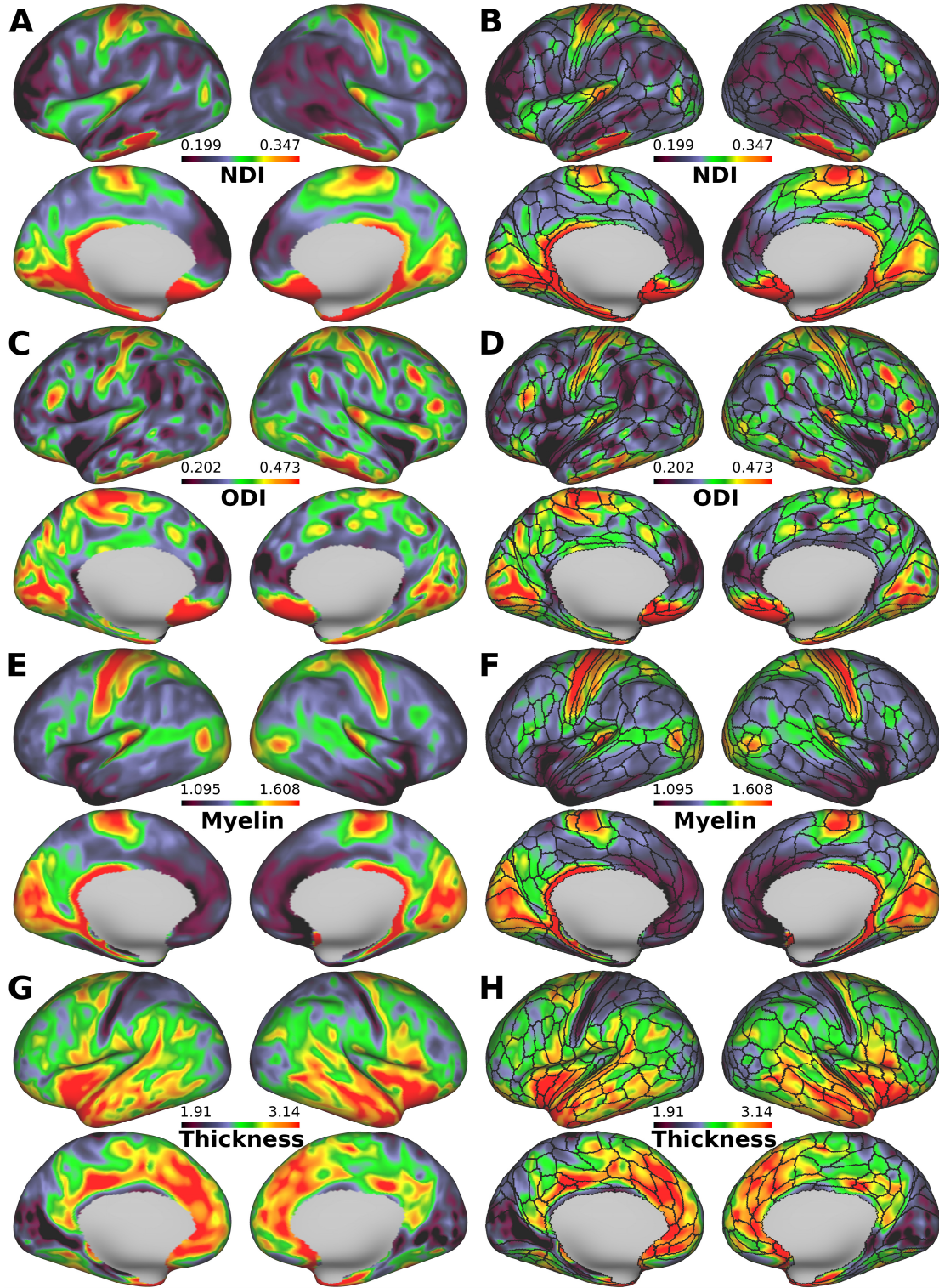


**Supplementary Figure S5.** 505-subject average maps of mean diffusivity (MD), fractional anisotropy (FA). (A) MD calculated using all DWI data (B) superimposed with the HCP parcellations (black lines). (C) FA calculated using all DWI data (D) superimposed with the HCP parcellations (black lines). (E) MD calculated using DWI data with  $b=1000$  s/mm<sup>2</sup> (F) superimposed with the HCP parcellations (black lines). (G) FA calculated using DWI data with  $b=1000$  s/mm<sup>2</sup> (H) superimposed with the HCP parcellations (black lines). Data at <https://balsa.wustl.edu/912k>



**Supplementary Figure S6.** Signal-to-noise ratio (SNR), neurite density index (NDI) and orientation dispersion index (ODI). **A)** The SNR surface map is superimposed with the Human Connectome Project (HCP) parcellations. The blue borders indicate parcels where SNR is <17. **B)** The bar graph shows mean and standard error of NDI and ODI in each area of SNR<17 (n=29) and SNR>17 (n=331). Data at <https://balsa.wustl.edu/k3k2>

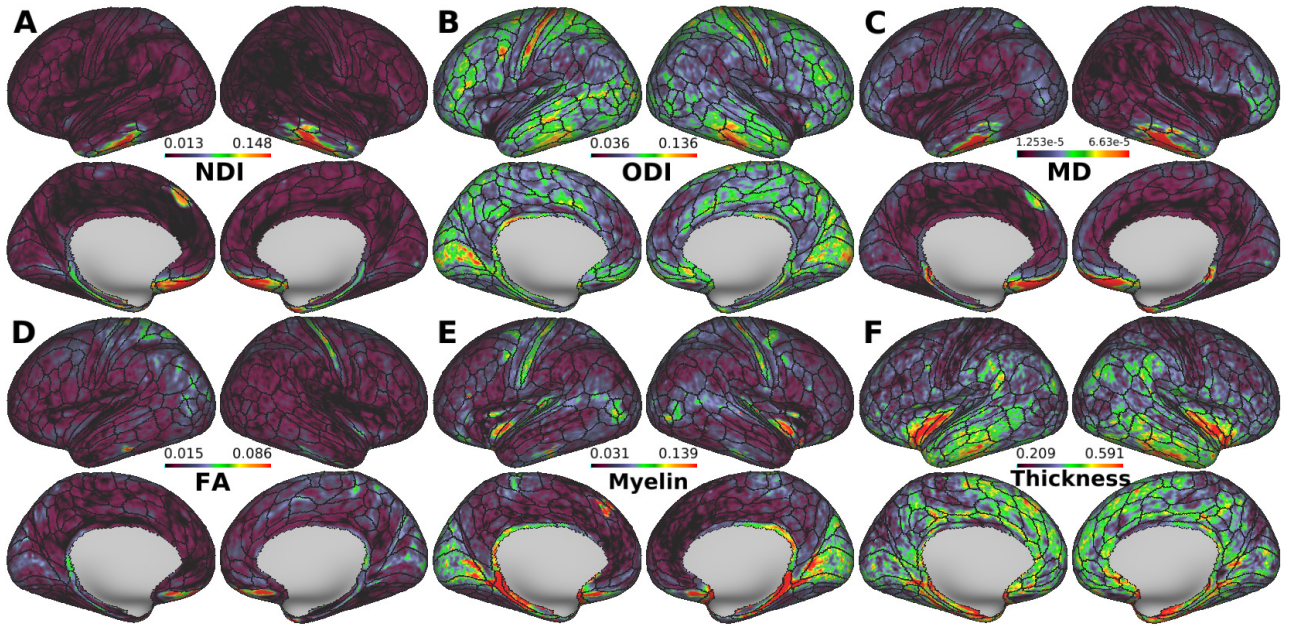




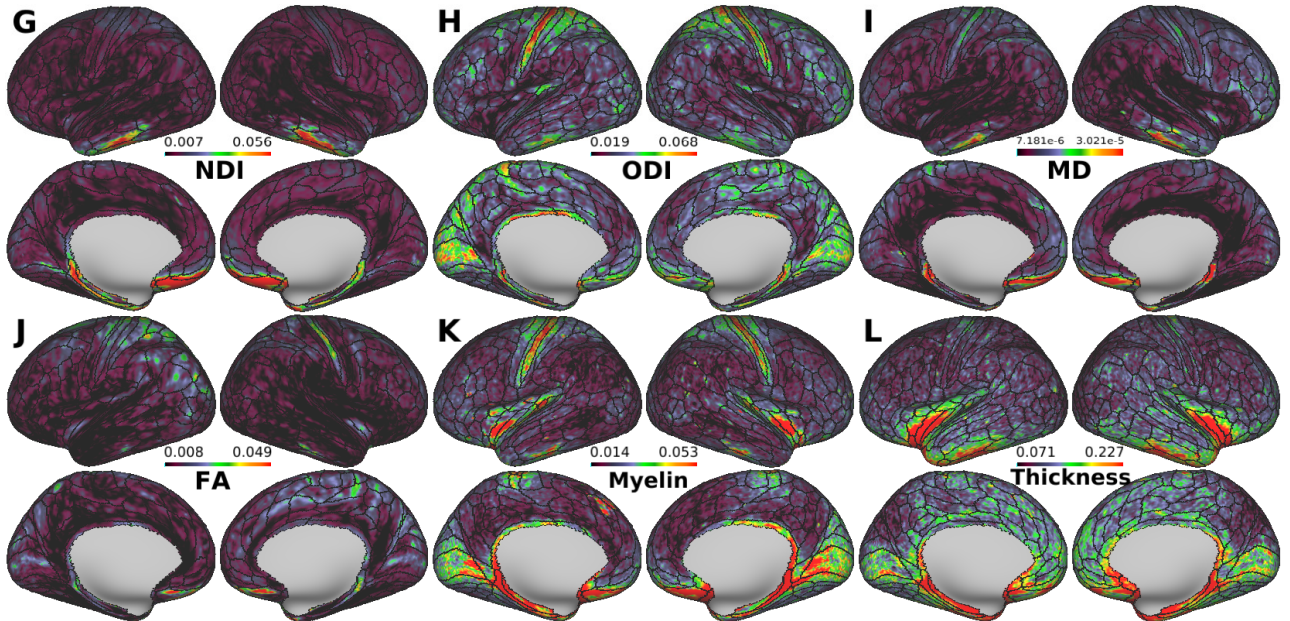
**Supplementary Figure S7.** Single-subject orientation dispersion index (ODI) and neurite density index (NDI) cortical maps from the Human Connectome Project (HCP) data. The surface metrics have been smoothed with 5-mm FWHM surface geodesic Gaussian smoothing. **(A)** Neurite density index (NDI), **(C)** orientation dispersion index (ODI), **(E)** myelin and **(G)** cortical thickness. **(B, D, F and H)** The imaging modalities superimposed with the boundaries of the Human Connectome Project (HCP) multimodal parcellations (black lines). This representative single-subject shows similar cortical distribution patterns of ODI and NDI compared with 505-subject average maps (see **Fig. 1**). Data at <https://balsa.wustl.edu/094/>



## Inter-subject variability



## Coefficient repeatability of HCP test-retest data



**Supplementary Figure S8.** Inter-subject variability and within-subject repeatability of cortical surface metrics, including NODDI. (A-F) shows inter-subject variability (standard deviation) of HCP test-retest subjects ( $n=32$ ). (G-L) shows coefficient repeatability of HCP test-retest data ( $n=32$ ). (A,G) Neurite density index (NDI), (B,H) orientation dispersion index (ODI), (C,I) mean diffusivity (MD), (D,J) fractional anisotropy (FA), (E,K) myelin and (F,L) cortical thickness. The imaging modalities superimposed with the boundaries of the Human Connectome Project (HCP) multi-modal parcellations, 210P MPM (black lines) (Glasser et al, 2016). Data at <https://balsa.wustl.edu/20NG>