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Supplemental information

Mapping of neuronal and glial primary cilia contactome and connectome in the human cerebral cortex

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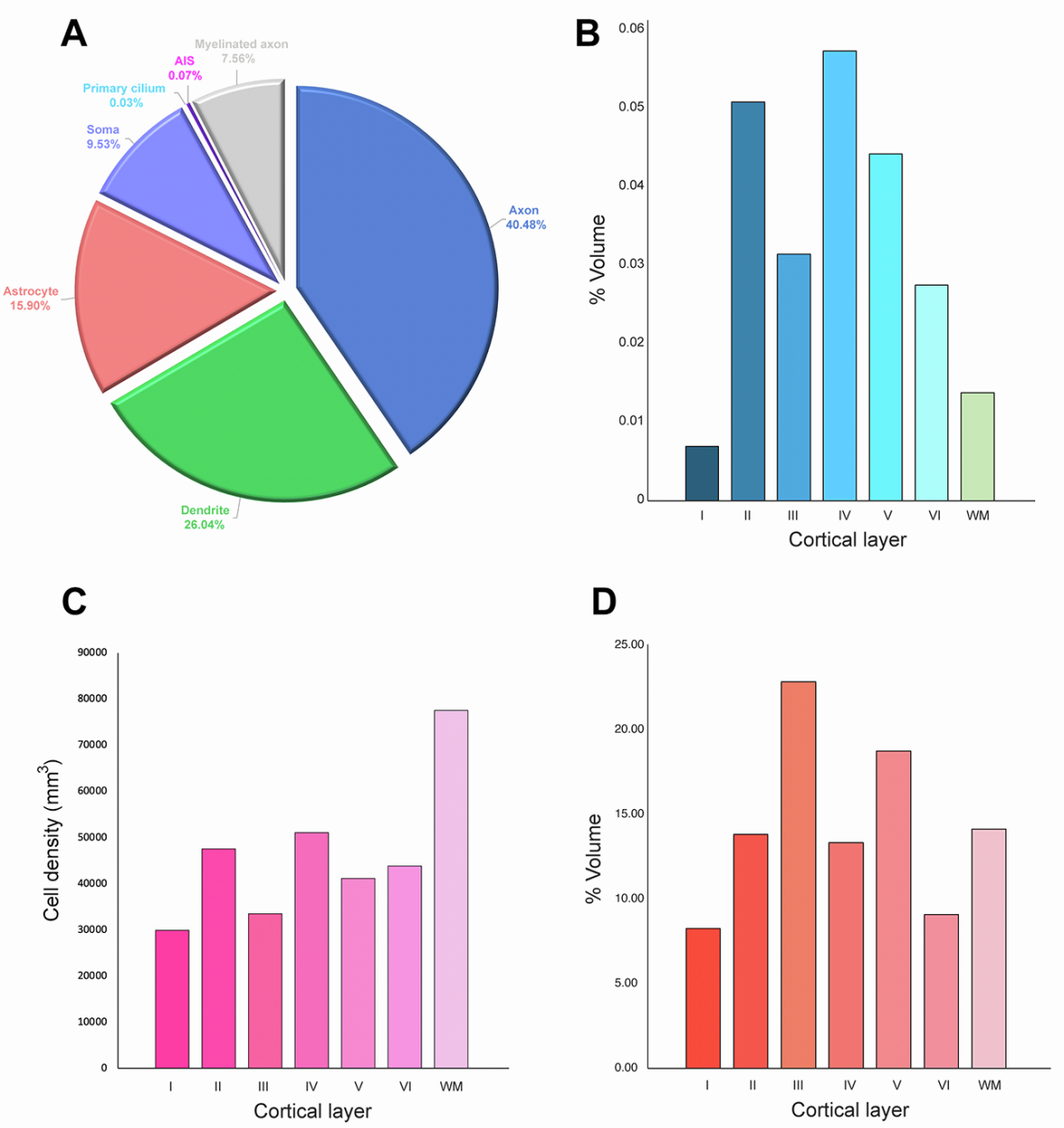
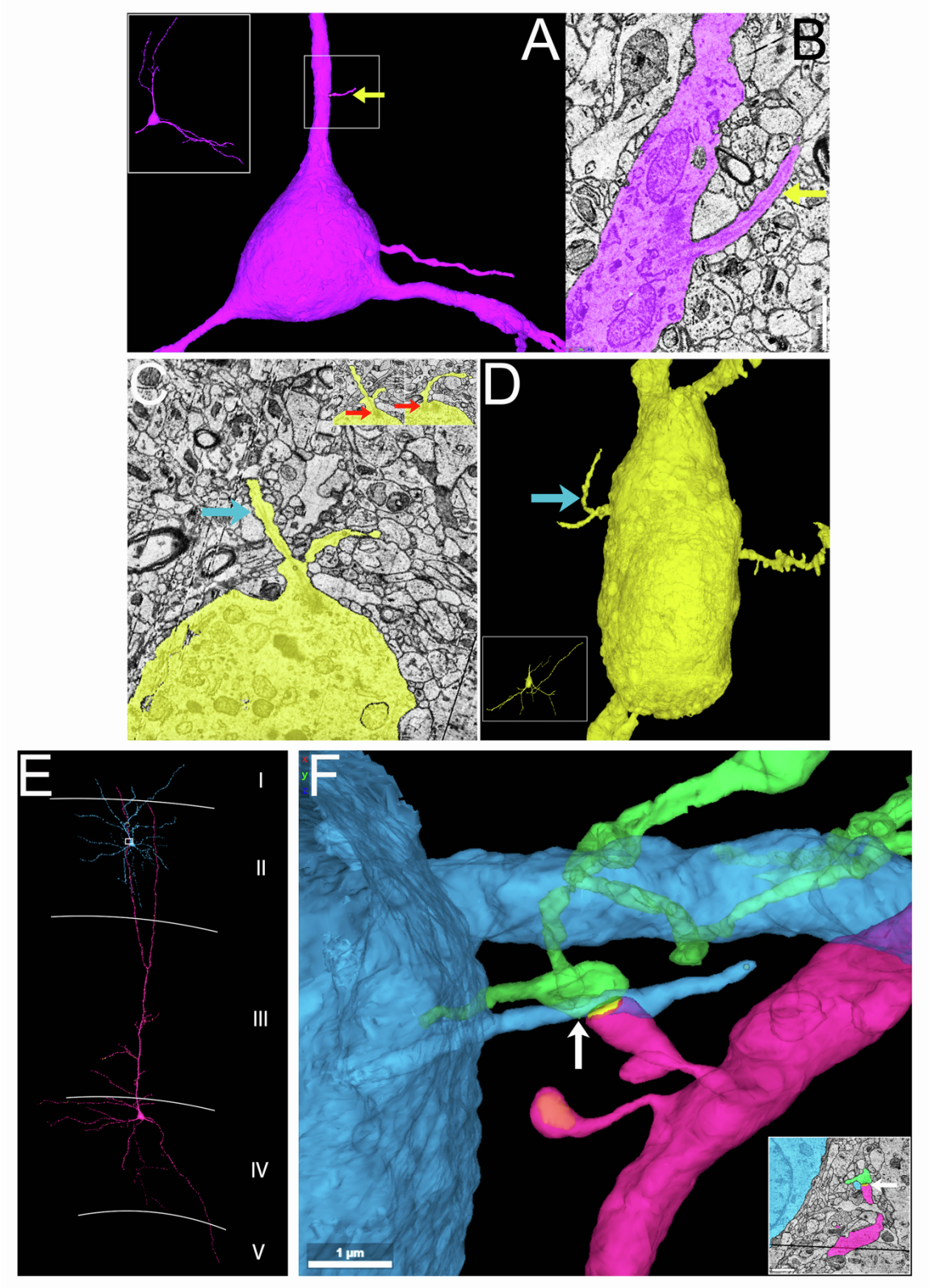
Supplemental Information

Supplemental Figures

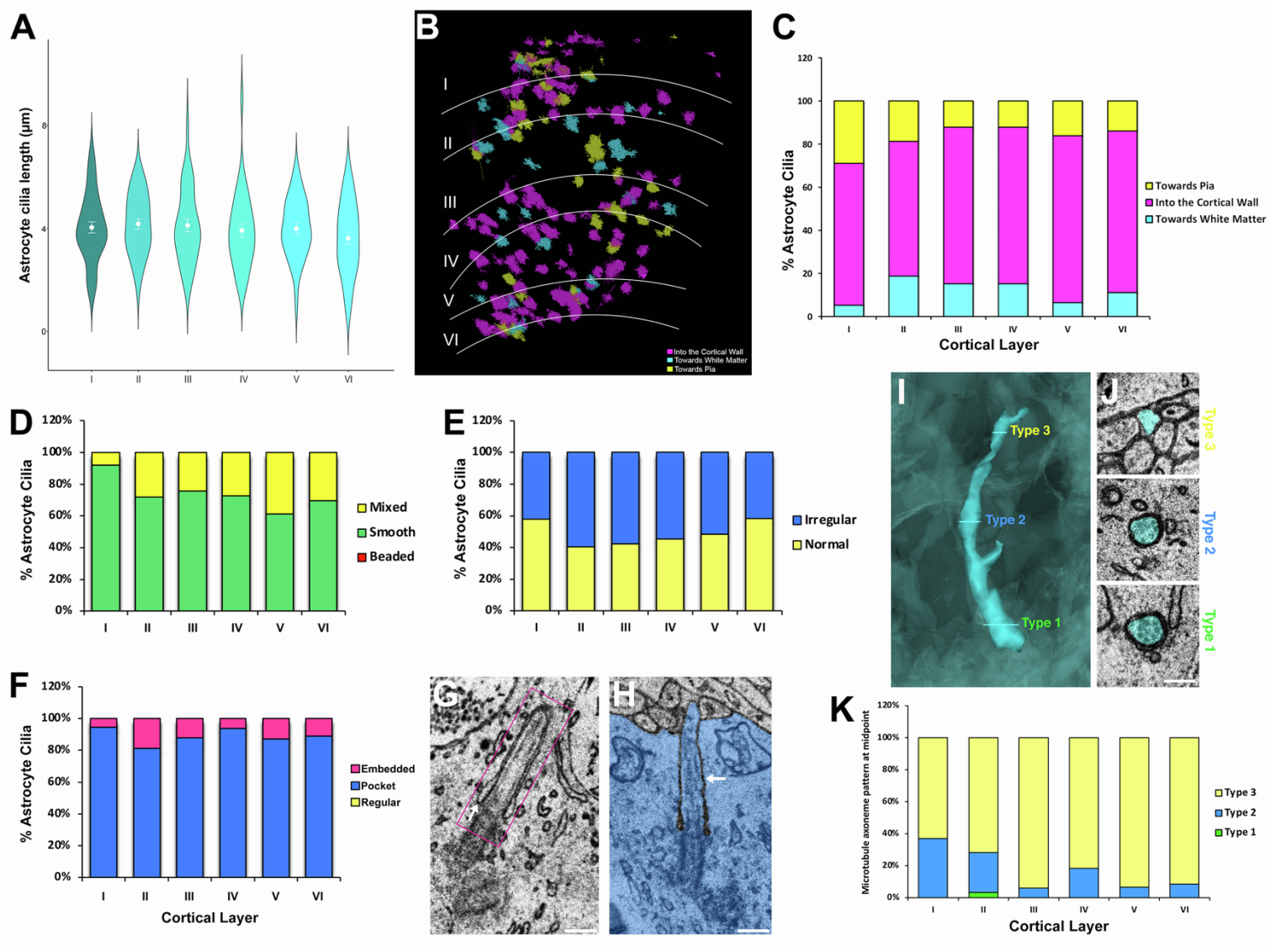


Supplemental Figure 1. Cortical volume occupied by primary cilia (Related to Figures 1, 2, and 3). Relative volume occupied by the primary cilia, other cell domains, and cell types in the cerebral cortex (A; modified from Shapson-Coe et al[36]). Layer-specific volume occupancy of primary cilia (B). Relative cellular density (C) and volume (D) of each layer for comparison.



Supplemental Figure 2. Atypical cortical neuronal cilia (Related to Figures 2 and 3). A cilium extending from the dendrite of a layer 5 interneuron (arrow, A-B). Inset in panel

A shows the entire neuron. Panel B is an EM section of the boxed area in panel A. (C-D) An example of a neuron with what appears to be two cilia. In this layer 4 interneuron, two ciliary axonemes (blue arrow, C, D) appear to extend from two basal bodies (red arrow, C). Inset in panel D shows the entire neuron. (E-F) Atypical long-distance contact of a neuronal cilium. A layer 4 projection neuronal dendrite contacts a layer 2 projection neuronal primary cilium (E). The contacting dendrite (pink) and the neuronal cilium (blue) are components of an excitatory synapse (yellow [arrow],F). Inset (F) shows the EM micrograph of this contact. The synapse (green [pre]/pink [post]; arrow) and the cilium (blue) are highlighted.



Supplemental Figure 3. The organization and structure of astrocyte primary cilia (Related to Figures 4 and 7). (A) Quantification of the average length of astrocyte primary cilia from layers I and VI. Data shown are mean ± SEM. One-way ANOVA (cilia length): P>0.05.

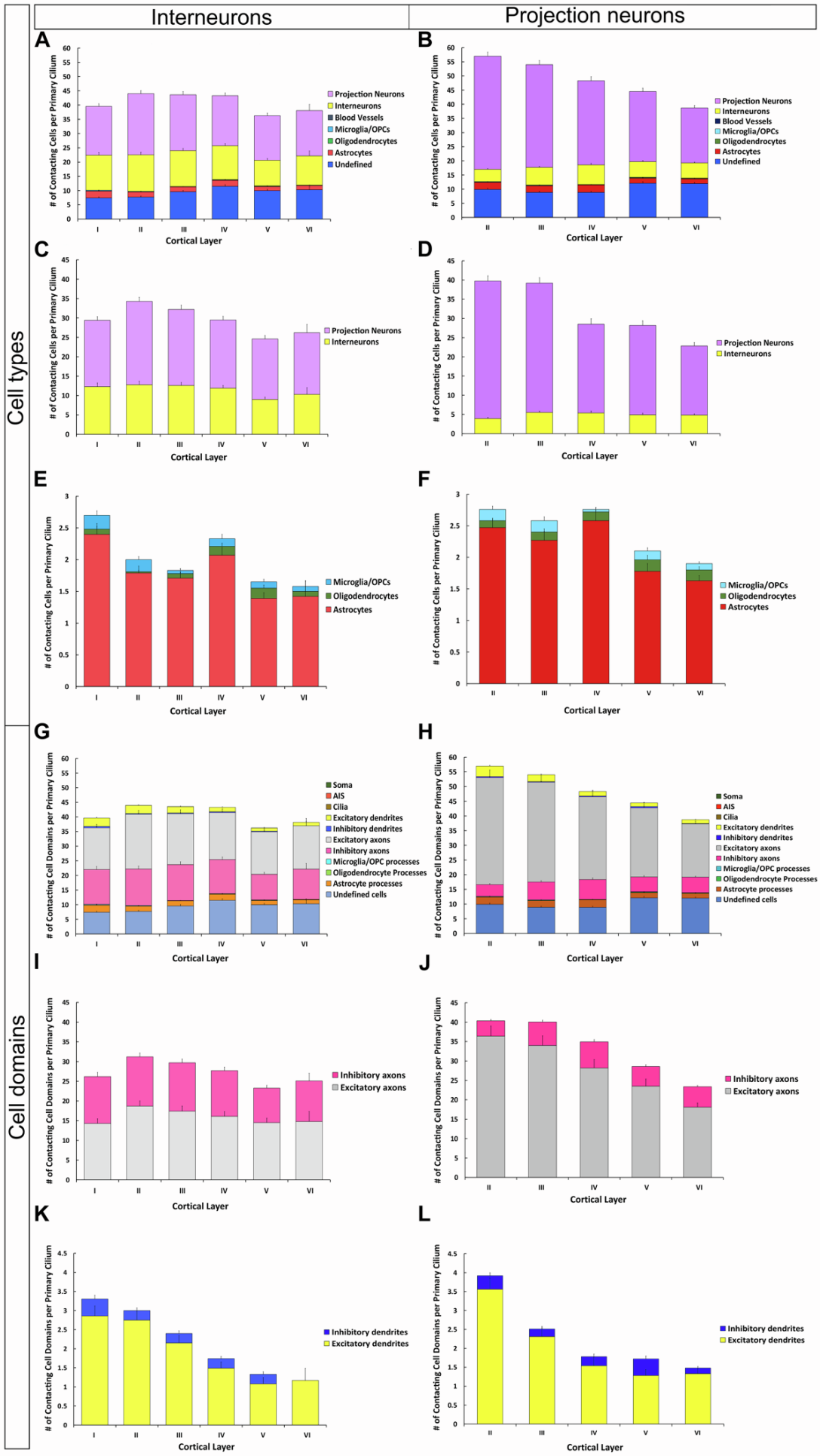
(B-C) Astrocyte primary cilia orientation. (B) The layer location of astrocytes with different cilia orientations. Cells are highlighted in colors corresponding to different cilia orientation. (C) Quantification of astrocyte primary cilia orientation (i.e., towards the pial surface, white matter, or into the cortical wall). Astrocytes from different cortical layers (I-VI) were quantified. One-way ANOVA (orientation): $F_{2, 15} = 147$, $p = 1.4E^{-11}$.

(D) Quantification of astrocyte cilia shape. I-VI, cortical layers. One-way ANOVA (cilia type): $F_{2,10}$= 79.7, p =0.00029.

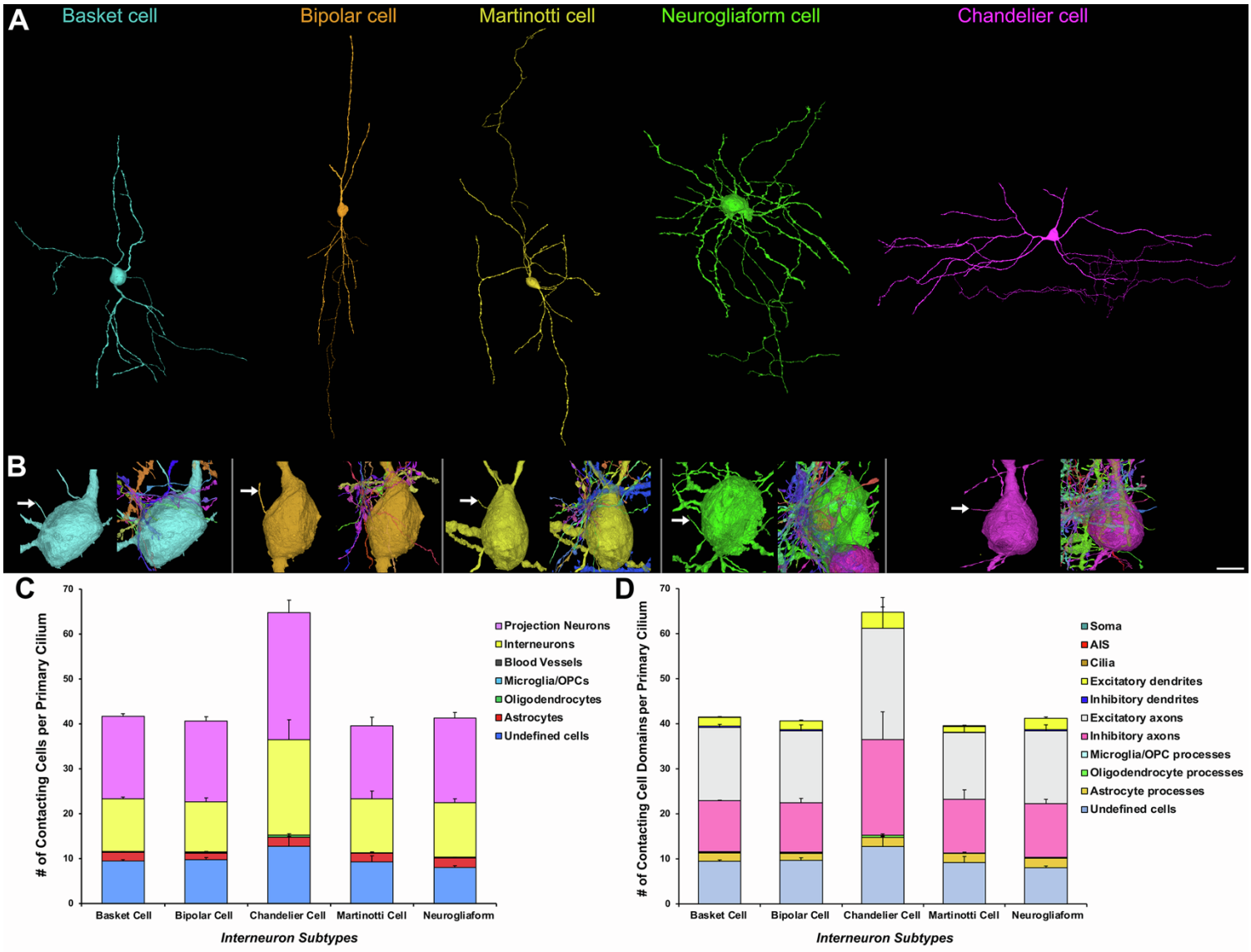
(E) Quantification of basal body organization (normal or irregular) of astrocyte cilia. I-VI, cortical layers. One-way ANOVA (basal body organization): P>0.05.

(F-H) Organization of astrocyte primary cilia. Quantification of astrocyte ciliary axoneme fully embedded within a ciliary sheath inside the soma (F, G [box]) and cilia extending from a ciliary pocket at the base (F, H [arrow]). The axoneme of the astrocyte primary cilium in panel G (box) does not extend outside the cell surface. Arrow (G) indicates ciliary sheath. (*Also see Supplemental Movie 5*). I-VI, cortical layers. One-way ANOVA (ciliary organization): $F_{2, 10}$= 543.3, p =6.3E^{-11}. Scale bar: 0.35μm (G-H).

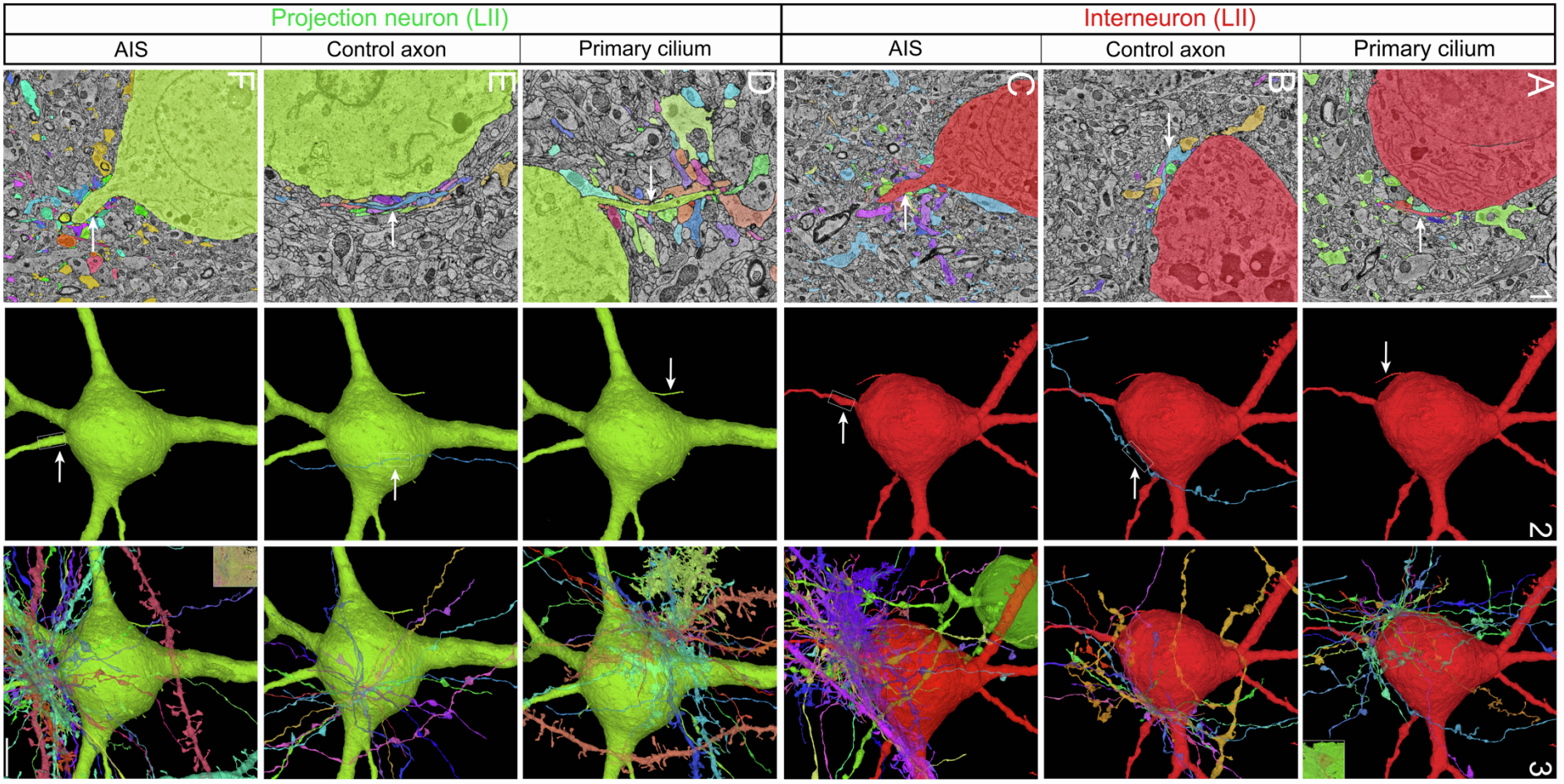
(I-K) Changing dynamics of axoneme MT core of astrocyte primary cilia. Quantification of the extension of MT filaments within astrocyte cilia from different layers. (I-J) Sample images of cross sections from the base, middle, and tip of an astrocyte cilium. Cross sections containing 9-8, 7-4, and 3 or fewer MT doublet filaments are classified as type 1, 2, and 3, respectively. (K) Quantification of the MT type at the midpoint of astrocyte cilia from different layers. I-VI, cortical layers. Data shown are mean ± SEM. One-way ANOVA: $F_{2, 10[\text{MT organization-midpoint}]}$ = 69.6, p=1.3E^{-6}.


Interneurons
Projection neurons
Cell types
Cell domains
A
B
C
D
E
F
G
H
I
J
K
L
# of Contacting Cells per Primary Cilium
# of Contacting Cell Domains per Primary Cilium
Cortical Layer
I
II
III
IV
V
VI
Projection Neurons
Interneurons
Blood Vessels
Microglia/OPCs
Oligodendrocytes
Astrocytes
Undefined
Soma
AIS
Cilia
Excitatory dendrites
Inhibitory dendrites
Excitatory axons
Inhibitory axons
Microglia/OPC processes
Oligodendrocyte Processes
Astrocyte processes
Undefined cells

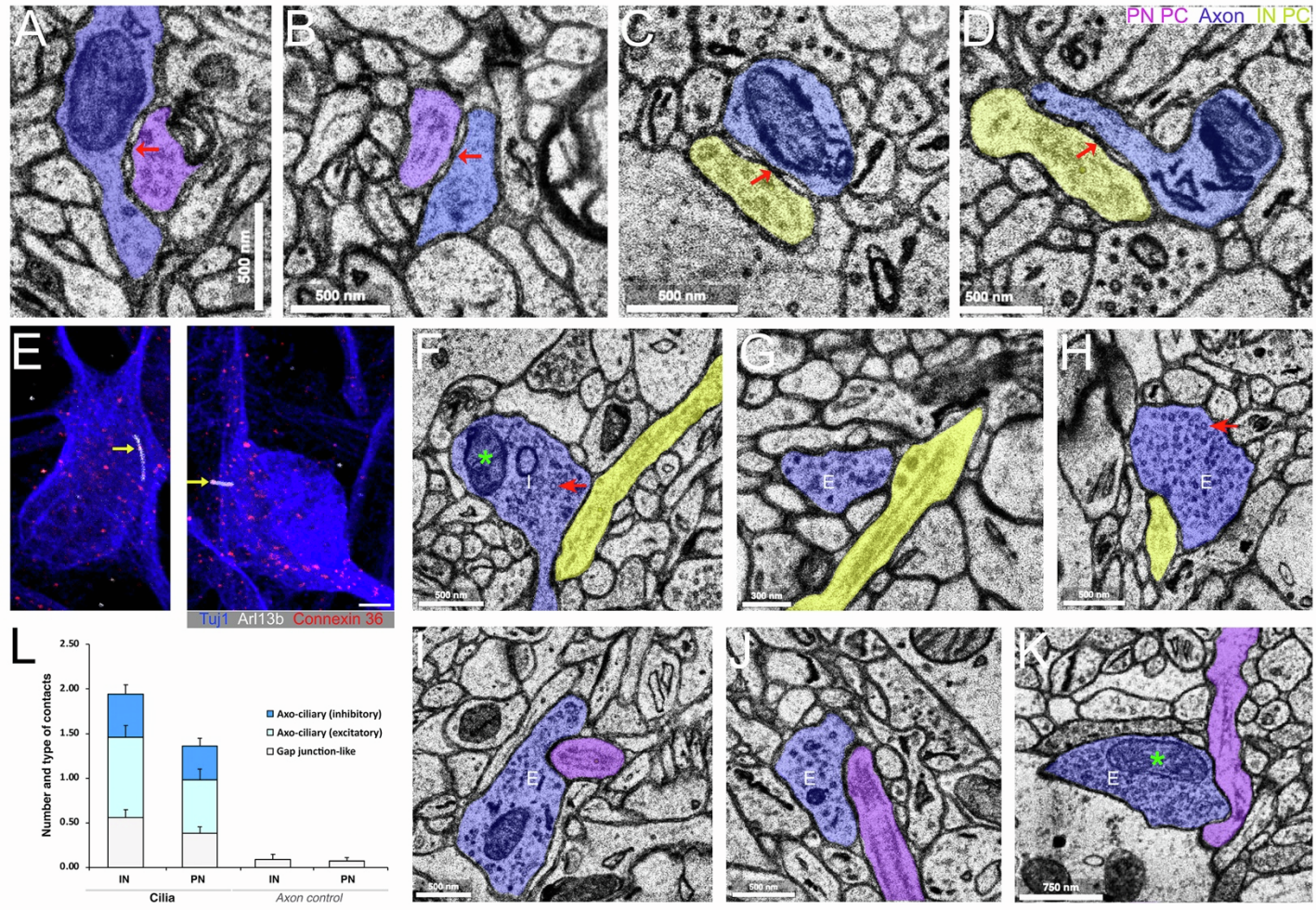
Supplemental Figure 4. Quantification of cortical neuronal primary cilia contactome (Related to Figures 5 and 6)**.** Cell types (A-B) and different cell domains (G-H) contacting the primary cilium of different cortical interneurons (A, C, E, G, I, K) and projection neurons (B, D, F, H, J, L) were quantified. Panels C-D and E-F illustrate the differences in cilia-contacting neuronal and glial types, respectively. Panels I-J and K-L illustrate the differences in cilia-contacting axonal and dendrite types, respectively. I-VI, cortical layers. Data shown are mean±SEM. Two-way ANOVA (cell types, IN vs PN): Layer II, p= 0.01; Layer III, p= 0.0012; Layer IV, p= 0.006; Layer V, p= 0.002; Layer VI, p= 0.0004. Two-way ANOVA (cell domains, IN vs PN): Layer II, p= 0.002; Layer III, p= 0.0016; Layer IV, p= $3.5E^{-4}$; Layer V, p= $5.5E^{-5}$; Layer VI, p= $2.4E^{-6}$.



Supplemental Figure 5. Quantification of interneuronal primary cilia contactome and organization (Related to Figure 5). (A) Different types of cortical interneurons. (B) Primary cilium of each of these neurons (arrow, right panels) and all the cells contacting them (left panels, B). Cell types (C) and different cell domains (D) contacting the primary cilium of different subtypes of cortical interneurons were quantified. Data shown are mean±SEM. Two-way ANOVA (cell types): $F_{4,199[\text{cell types}]} = 3.041$, $p = 0.018$, post-hoc $p_{[\text{projection neurons, Chandelier cells versus other IN cell types}]} < 0.05$. Two-way ANOVA (cell domains): $F_{4,228[\text{cell domains}]} = 2.591$, $p = 0.037$, post-hoc $p_{[\text{excitatory axons, Chandelier cells versus other IN cell types}]} < 0.05$. Scale bar: A, 60µm; B, 15µm.

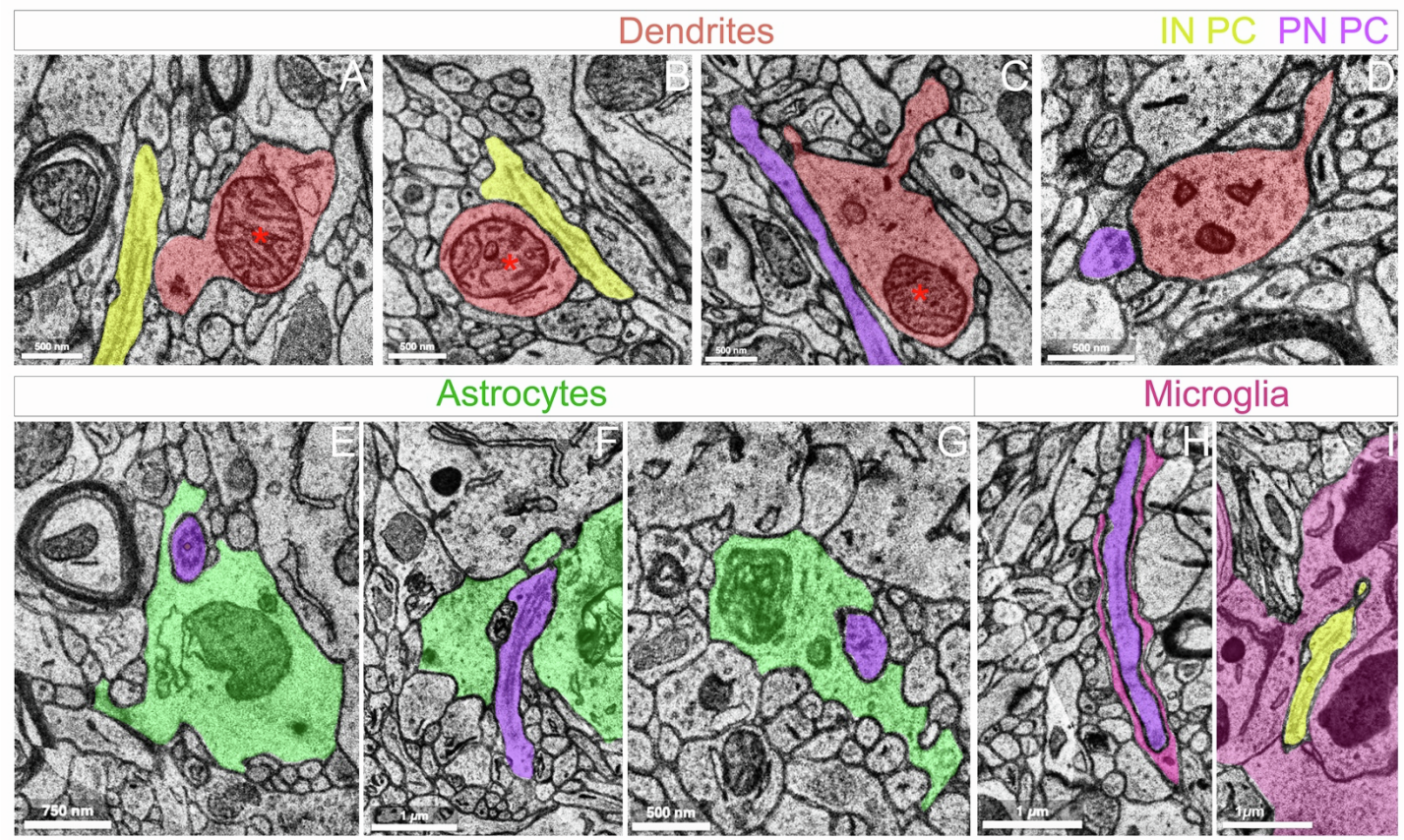

Projection neuron (LII)
Interneuron (LII)
AIS
Control axon
Primary cilium
AIS
Control axon
Primary cilium
F
E
D
C
B
A
1
2
3

Supplemental Figure 6. Control axon segment and AIS contactome (Related to Figures 5, 6, and 7). Primary cilium of a cortical interneuron (arrow, columns 1 and 2; A) and all the axons and dendrites of other neurons as well as the non-neural cells contacting it (column 3; A). Column 1 shows electron micrograph of the relevant cilium (arrow) and its contacting cells. Control axon segment (arrow, columns 1 and 2; B) and all the cells contacting it (column 3; B) as illustrated for the cilium. AIS (arrow, columns 1 and 2; C) and all the cells contacting it (columns 3; C) as illustrated for the cilium. Connectome of a projection neuronal cilium, control axon segment, and AIS are similarly illustrated in rows D, E, and F. Control axon segments and AIS are of the same length and phenotype (excitatory or inhibitory) as the relevant primary cilium. Insets (Column 3, A and F) show astrocytes, which were removed for clarity from the larger image. Scale bar: 2.6μm (column1); 6.6μm (columns 2-3).

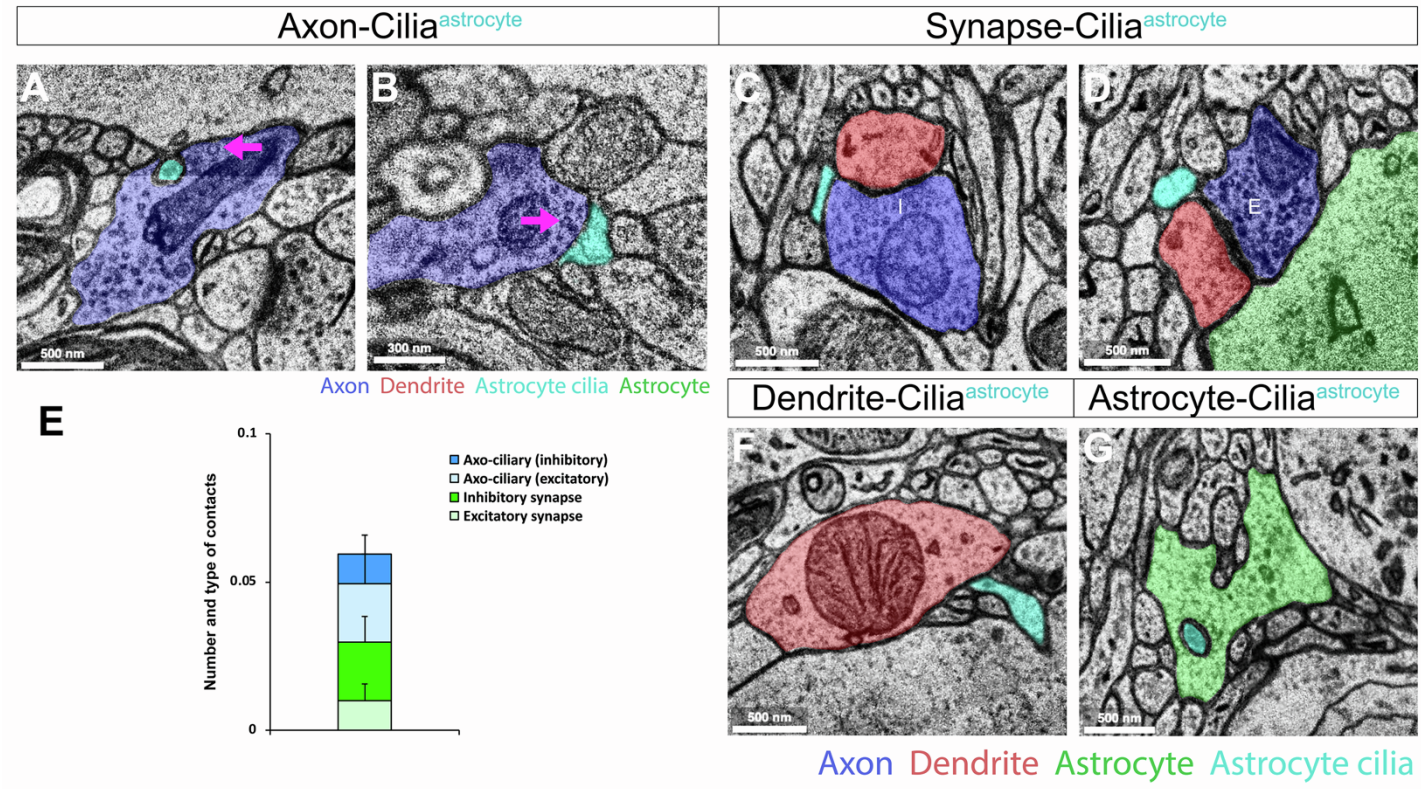


Supplemental Figure 7. Diversity of neuronal primary cilia-axon contacts (Related to Figures 5, 6, 8, and S4). (A-D). Gap junction-like neuronal primary cilia-axon contacts. Neuronal primary cilia can make gap junction-like contacts with axonal domains (arrow, A-D). Arrows indicate electron dense intercellular gap junction like contacts. (E) Expression of neuronal GAP junction hemichannel, connexin-36, in human cortical neuronal cilia (arrow). (F-K) Axo-ciliary contacts. Neuronal primary cilia make membrane contacts with axonal domains that are enriched in synaptic vesicles (arrows, F-K). Some cilia-contacting axonal domains also contain mitochondria (asterisk, F, K). Axonal type (excitatory [E] and inhibitory [I]) is indicated in each panel. (L) Quantification of different types of neuronal cilia-axon contacts. Data shown are mean±SEM. Student's t-test (axo-ciliary contacts or gap junction-like contacts): IN_{cilia} vs $IN_{axon\ control}$, $P<0.05$; PN_{cilia} vs $PN_{axon\ control}$, $P<0.05$. Yellow and purple indicate primary cilia from inhibitory and excitatory neurons, respectively. IN PC, interneuron primary cilia; PN PC, projection neuron primary

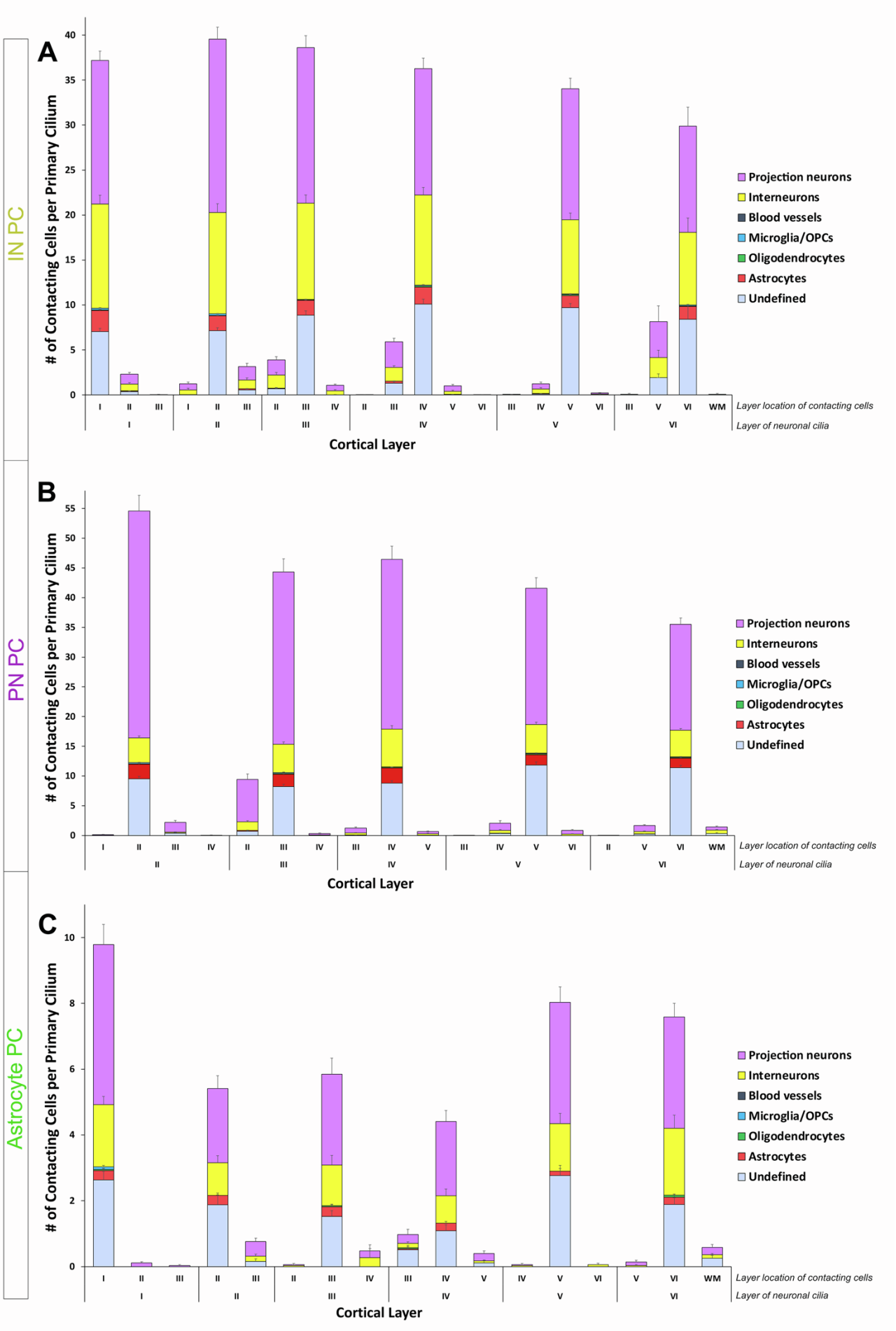
cilia. Scale bar: 3.125μm (E). Neuroglancer links to images in A-D and F-K are as follows- A, B, C, D, F, G, H, I, J, K.



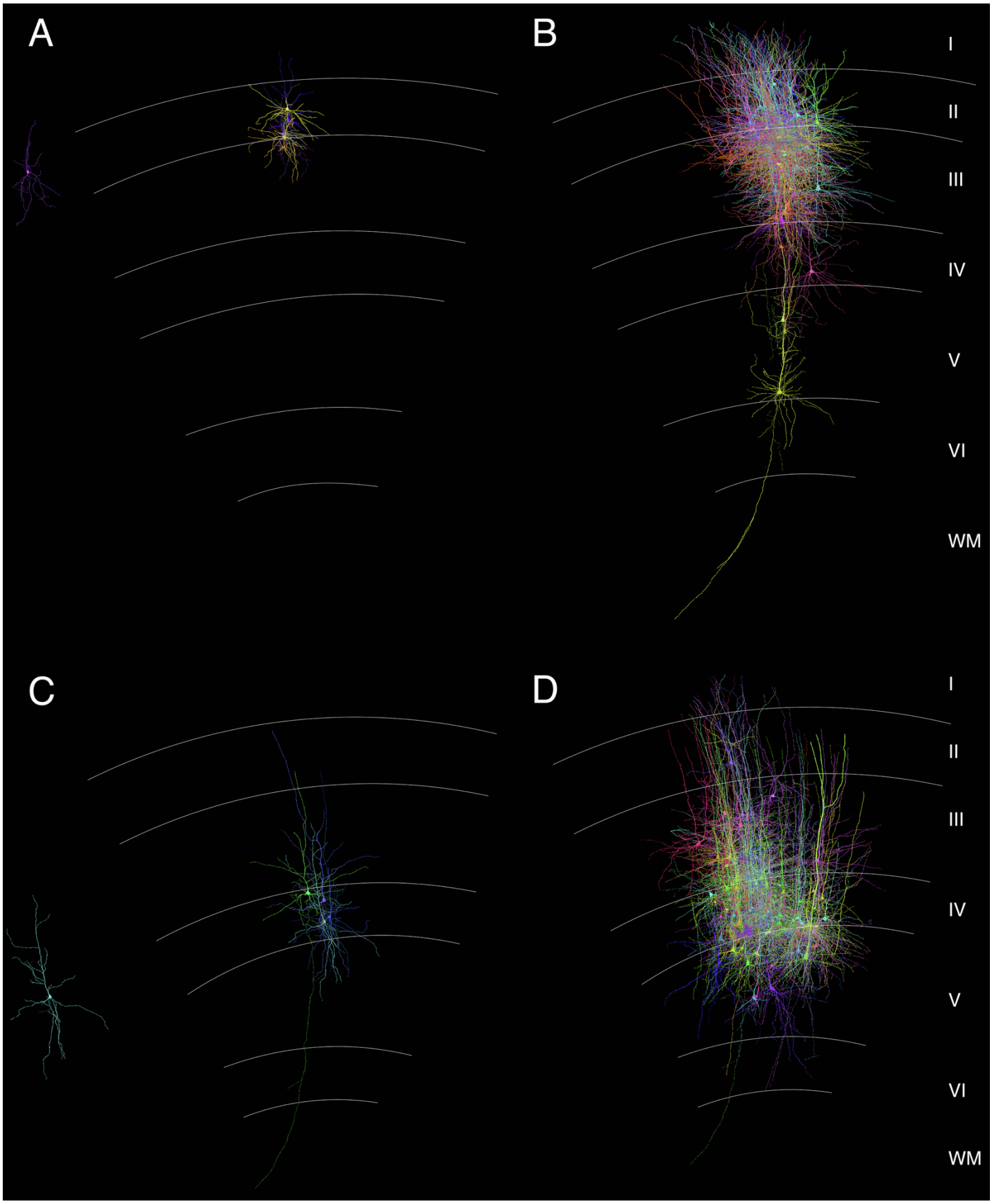
Supplemental Figure 8. Neuronal primary cilia contacts with dendrites and glia (Related to Figures 5, 6, and S4). **(**A-D) Neuronal primary cilia make membrane contacts with dendritic spines. Some of the dendritic spines have large mitochondria (asterisk, A-C). (E-G) Neuronal primary cilia are often encircled by astrocytes. (H-I) Microglial encirclement of projection neuronal (H) or interneuronal (I) primary cilia. Primary cilia from inhibitory and excitatory neurons are highlighted in yellow and purple, respectively. Astrocytes and microglia are colored green and magenta, respectively. IN PC, interneuron primary cilia; PN PC, projection neuron primary cilia. Neuroglancer links to images in A-I are as follows- A, B, C, D, E, F, G, H, I.



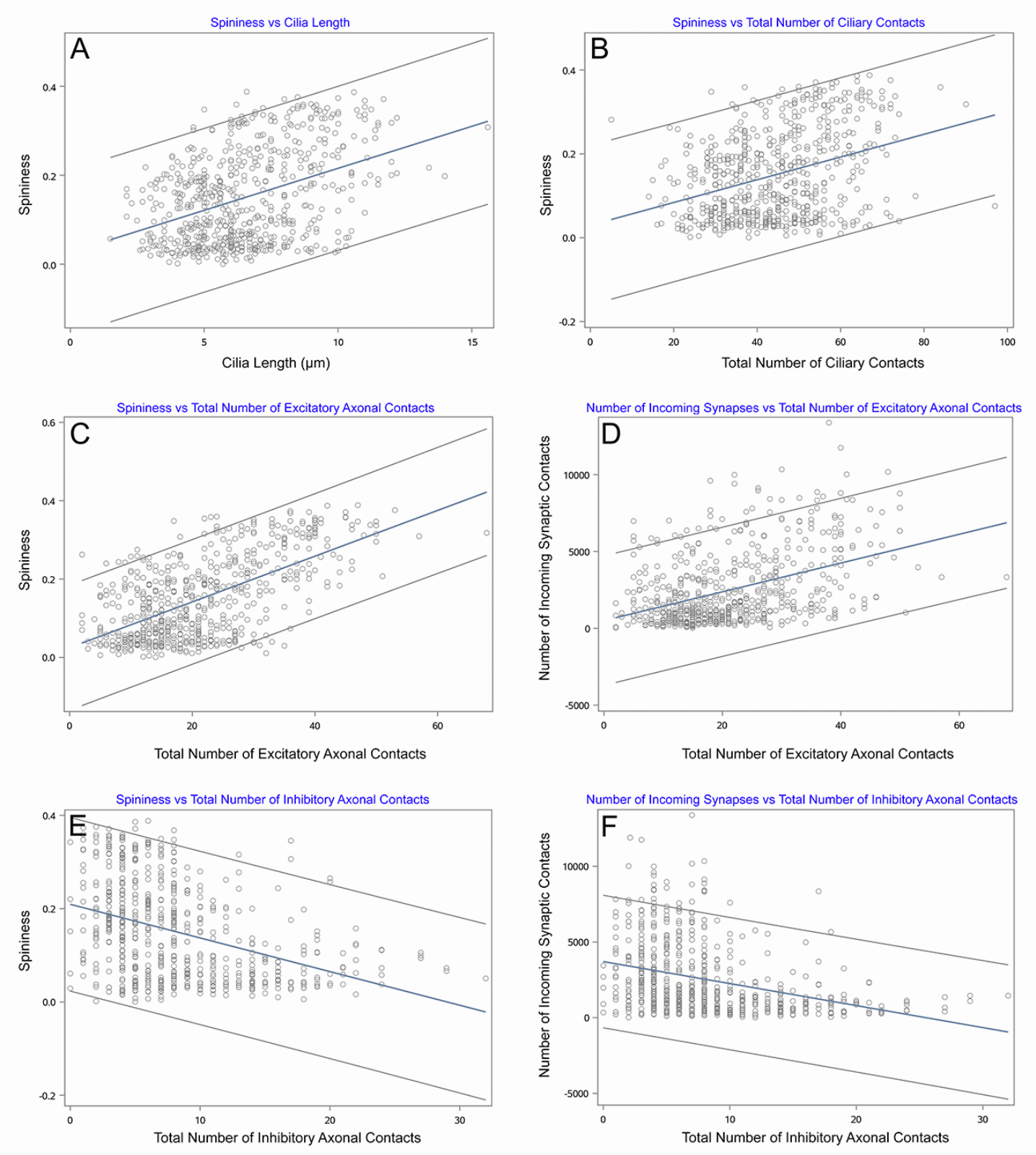
Supplemental Figure 9. Diversity of astrocyte primary cilia contacts (Related to Figure 7). (A) Axo-ciliary contacts. Astrocyte primary cilia (teal) make membrane contacts with axonal domains that are enriched in vesicles (arrow, A-B). (C-D) Astrocyte primary cilia (teal) can also associate with synapses. Synapse type (excitatory [E] and inhibitory [I]) is indicated in each panel. (E) Quantification of different types of astrocyte cilia-axon and -synapse contacts. Astrocyte cilia also come in contact with dendritic spines (F) and are encircled by other astrocytes (G). Neuroglancer links to images in A-G are as follows- A, B, C, D, F, G.


IN PC
PN PC
Astrocyte PC
A
B
C
# of Contacting Cells per Primary Cilium
Cortical Layer
Layer location of contacting cells
Layer of neuronal cilia
Projection neurons
Interneurons
Blood vessels
Microglia/OPCs
Oligodendrocytes
Astrocytes
Undefined

Supplemental Figure 10. Cortical layer origin of primary cilia contacting cells (Related to Figures 5, 6, and 7). The layer location of cells contacting the primary cilium of interneurons (A), projection neurons (B), and astrocytes (C) of each cortical layer was quantified. The majority of cellular contacts of a neuronal or glial cilium originated from the same or adjacent layer. IN, interneuron; PN, projection neuron; PC, primary cilia; I-VI, cortical layers. Data shown are mean ± SEM.

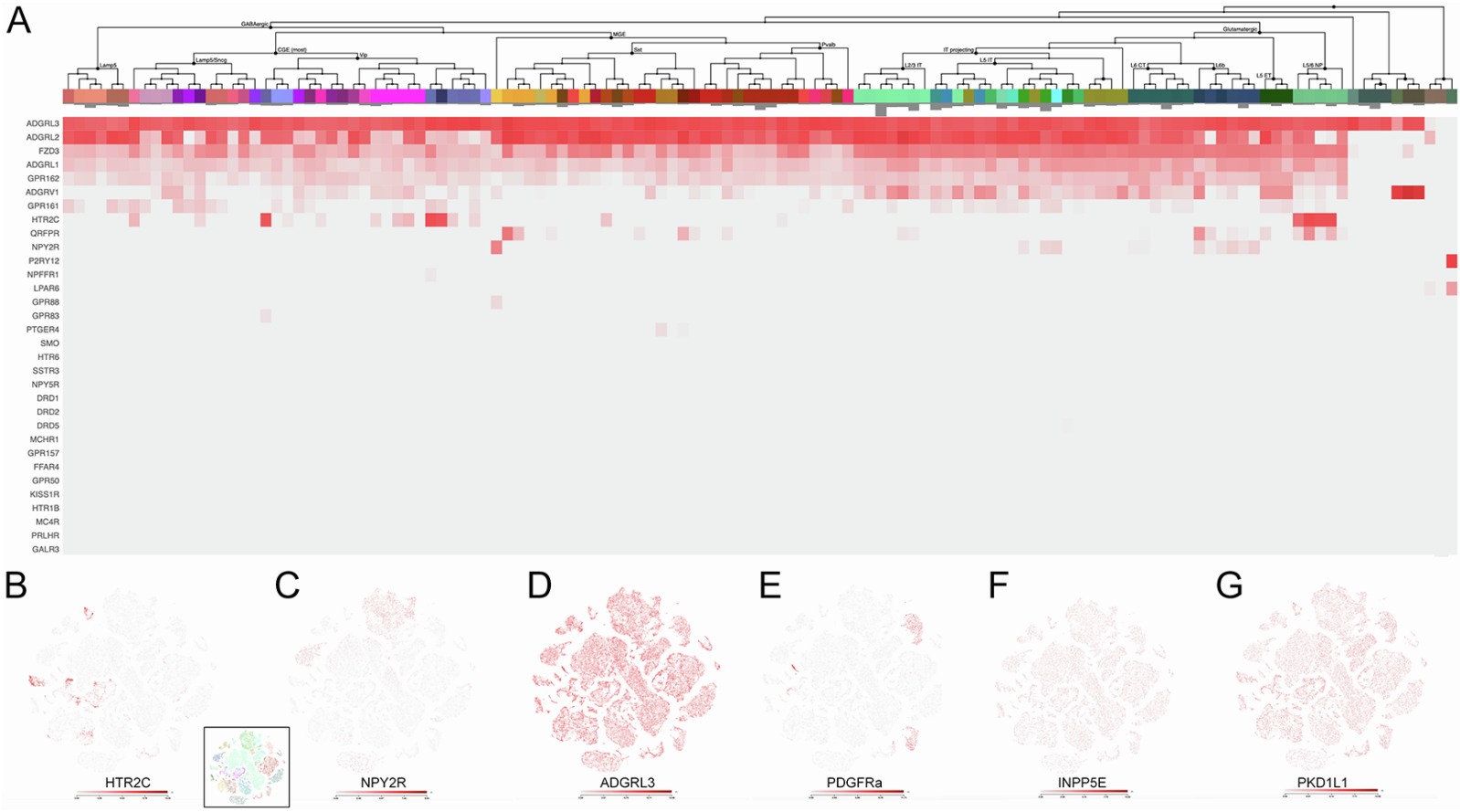

A
B
I
II
III
IV
V
VI
WM
C
D
I
II
III
IV
V
VI
WM

Supplemental Figure 11. Distinct nature of primary cilia and neuronal connectome (Related to Figures 5, 6, and S4). Primary cilia connectome of a layer 2 interneuron (A) and a layer 5 projection neuron (C). Cells contacting the primary cilia of these neurons come from the same or adjacent layers (A and C). In contrast, the synaptic connectivity of these neurons is extensive and spans multiple layers (B and D, respectively). Astrocytes contacting the respective primary cilia or the neuron were excluded for clarity. Insets (left) show each neuron without its ciliary or synaptic contacts. I-VI, cortical layers.



Supplemental Figure 12. Relationship between neuronal cilia and spininess of cortical neurons (Related to Figures 5, 6, 8, and S7). (A) Cilia length is positively correlated with the spininess of neurons (Pearson's r, 0.41, $p<1E^{-16}$). Spininess of a

neuron is positively correlated with the total number of ciliary contacts (r, 0.352, $p<1E^{-16}$, B) and with the number of excitatory axonal contacts (r, 0.614, $p<1E^{-16}$, C) of a neuronal cilium. (D) The number of excitatory axonal contacts of cilia positively correlates with the number of incoming synapses to neurons (r, 0.43, $p<1E^{-16}$). (E-F) The number of inhibitory axonal contacts of cilia negatively correlates with the spininess (r, -0.39, $p<1E^{-16}$) and the number of incoming synapses to neurons (r, -0.34, $p= 1E^{-16}$).



Supplemental Figure 13. Human cortical neuronal expression of cilia-associated signaling receptors, ion channels, and second messengers (Related to Figures 1, 4, 5, 6, 7, 8, S1, S4, and S4). Adult human brain cell expression pattern of the GPCRs known to be associated with primary cilia (A). These cell surface signaling receptors were screened for their expression pattern in Allen Brain Atlas's adult human cortex and hippocampus cell type-specific RNASeq database (M1-10X Genomics). Scatter plots of expression of cilia-associated GPCRs in subsets of cortical neurons (HTR2C in VIP^+ INs [B], NPY2R in SST^+ INs [C]), and ADGRL3 in all cortical neurons [D]). Similarly distinct expression patterns were also noticed for other cilia-linked receptors (e.g., PDGFr in $LAMP5^+$ INs [E]), second messengers (e.g., INPP5E in all cortical neurons [F]), and ion channels (e.g., PKD1L1 in all cortical neurons [G]). Inset (B) shows reference cell type-specific atlas of the scatter plots (Hodge et al., 2019; Allen Brain Map, Cell Types Database: RNA-Seq Data [https://portal.brain-map.org/atlases-and-data/rnaseq]).

Figure	Panels															
Figure 8	**A:**	LI	LII	LIII	LIV	LV	LVI	**B:**	LII	LIII	LIII	LIV	LV	LVI	C	D
Supplemental Figure 7	A	B	C	D		F	G	H	I	J	K					
Supplemental Figure 8	A	B	C	D	E	F	G	H	I							
Supplemental Figure 9	A	B	C	D		F	G									

SUPPLEMENTAL TABLES

Supplemental Table 1. Identity of all the interneurons and projections examined in this study (Related to Figures 1, 2, and 3). Neuronal cell identity numbers with links to their location in Neuroglancer are listed for interneurons and projection neurons from all 6 cortical layers. (Please note the links are easier to access if the PDF is opened in Google Chrome instead of Adobe Acrobat).

Table 1: Cortical neuronal primary cilia

Interneurons with Primary Cilia						Projection Neurons with Primary Cilia				
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6
37146142910	2718663948	4638898421	32791599134	6165551025	33516085703	1450376143	3387696184	29193343834	6513769803	5015430105
1787105373	2120678770	4275786135	32661562811	4840261666	6017103252	2602073423	2542472136	6864952954	6907908318	5012275127
2137208420	3125257652	3882494653	3995330445	3630670085	39962851803	1144733018	3925990067	32370126505	5422636543	4196721639
3680606691	3505468100	5309538535	5190802710	3891078930	33866261968	3518798548	3590955885	32194884853	6077169826	4650667613
37263286765	30202520112	6270371417	33331734971	4198064933	5521456474	1087542412	3562439721	4302872019	7052633592	6382769913
1190245536	1451297107	38658046334	56268867905	4476359994	6570362443	31046662942	2702674358	4913528885	4691667594	6981906973
1394191353	3198787432	2351346522	3456758527	4679607351	6717175479	2091155727	5075775279	5075322225	5918005808	33471670504
3113022318	4946396640	3515979249	3531238060	5566456712	5580327531	2280501088	2629407821	5482019597	3120073110	4604762284
3156431067	30187598118	4858659202	4679722794	6544359249	34230002763	3722481176	2629129838	6326350514	3528902155	5348331739
4409589695	58560947015	30624168062	4756145379	6879101098	4472579416	3140018733	3459620418	6500949268	5581378299	7285402573
1423553872	58663315438	32444504548	5220472240	7039231083	5492502881	3402471987	4841385043	6677125078	4094208392	5273488042
1452668296	1130278365	37522862988	5453255395	31230444707	7401757982	3489216996	5075979625	3878288639	4215470603	6292434122
1729080661	1449763370	39547803419	5612478783	42428944531		2105961568	2993570100	4011683186	4415590654	4997922584
2005856933	1858285103	2031190321	2844816353	3165277795		30742013887	4306756083	4624107703	5900936104	4997353939
3360318069	2338920806	3605090256	3458174974	5335761695		1596327698	3358492873	5860360217	33693108475	5141786988
3403480065	2907424570	5061116204	3588896643	5814600156		1728497220	3852445941	32007131507	4389878275	5390718424
36330415163	2979713896	5177967272	3866563836	6340396662		1886902875	4450399407	3020714778	4492479490	5975007104
636444441	3359150816	5469125788	4491632837	6747400414		1931040660	2761371616	3399332888	4722533363	6410715337
3301154728	3636599493	32370272208	4856468392	33737933543		2950834375	2860905618	3529456529	4939724073	31708920904
4627598544	1801310916	32371237036	5146312557	4910564616		3256534868	3183397934	5380337105	5352771787	6904345674
38485858513	5384426784	39428921609	6121790491	4111160213		4363495628	3517950418	6342515021	6456401608	4706559981
460458122	5733156051	41819250669	13910213238	5887343270		2178659041	4741455769	32413053449	4197890854	5726746103
533711979	29459622174	41995120012	30372826830	6601988172		4800503033	5163674335	33170917656	4519330988	5841641104
1613060545	37581631856	1245656455	31568253559	33677281270		1522022884	5849014680	33184336456	5598008907	39714911298
402243212	37787097036	4361422065	38598226398	41902636649		2484316542	6067314832	2786572808	5872566163	5055406469
36942459652	38761962949	4624939761	38918762655	69358211160		2485369079	3430549988	3180420219	30036113523	5272919263
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5005850706	40320605179	5687893999	42138312710	4139325860		3518681641	2484069388	3923858755	4241562819	6162731760
36534317289	45617277589	5965472721	2742433932	4561615237		1392936586	2498888339	4157284371	5276699233	6251229281
36621675715	45878986196	6430938176	3135331454	6107131430		3097120902	3298206355	4404218019	4054800495	30995793577
57352977341	2369144469	29383098617	4302346100	6121834307		28717044681	4028123903	4535129012	3922677106	32874985597
53711736279	2587780387	29996426864	4710473618	4300856796		30538009064	5438945541	5891606808	6848234050	5216105078
1918849113	3504882559	32006576283	5817331865	5131492402		31557144036	2933472324	5931875589	4592526340	5754239725
520117544	36882405719	37113947425	32180430283	5188348808		1901152704	5689193184	3749127975	5159993420	6381703408
38034714996	40218295373	38585771987	33418434625	5335030417		39112226336	852830461	3254783068	3222499167	5216747637
45021732268	4043892994	1886245145	37970340183	4737485281		36533601596	4406450407	3922442762	5654092357	5234152619

4380314835	5164550020	2366705935	37985028964	4343419233		28571136739	2789944495	3998937770	5799532727	5189021397
3594737701	37786221088	32588893142	39879625402	42529034364		36138629591	2307965742	4695405082	3008550652	5389697163
4002616369	30551674827	38804992102	51426052246	4489384273		37976035229	3809752632	4753414558	5917684171	5668839584
491470940	5908382258	5453780789	3530406006	6660510250		27667130272	4930830982	4899818199	5814309652	31419410828
1730029758	37262192364	4363436095	40958245296	3658558300		3111531808	2351622488	5104816512	3443968258	4210329807
1263103927	2616018803	4930116577	42225990497	3325450780		2675269381	3168855453	5132280723	4197686564	31460631882
3521018165	4568230875	5629853784	2728344352	5393507695		4830040033	1667872789	5935014505	2872995228	6105802392
2138112811	29139188774	32444357870	13092966158	3498414218		2077460715	3897139701	6007246666	3745551509	33953035801
2167328640	2659353359	41644462221	30913165738	6165009450		3578646904	3256008975	6328015219	4853649886	4472068090
55766359917	1480119406	41265450123	3807269209	67494392965		3824820293	5425833823	4462751886	6325270042	6571050167
695140502	36938079094	3953616201	29250930372	4561571429		29110569948	4552416806	4374709076	6425769635	7516202205
343606869	2557789796	3735023422	5248344086	6265684619		2601212268	2863184351	5861148055	6354268105	23921710148
359185130	2324932486	6255244644	32836028865	38740557584		2485090217	2396754193	2030050061	4475878153	30923589906
5472060932	925485691	2497121775	2713962340	25220483055		1989663691	4289131873	5117358943	7081689438	6278999548
	1069962332	3458613090	37882747944	6500176105		4713684670	5353501752			33546616234
	2470373696	42256916348	20864727467			5718116647	4479995708			5184873511
	3214192411	65019948281	31991127834			1843099641	3167438862			5462089350
	49390132072	29835261616	3805153314			4845941742	4319925653			6718066168
	40640688374	59885243362	6721015852			2456488265	4538560279			5898892521
	48807815597	3181937794	64478586301							4476038951
	882090316	2846816391	6779098861							4998273531
	1333290325	41440369640								6426367387
	1887575004	38527617086								6556053420
	39767314376									6584686007
	1727591544									6731470222
	40742704980									7079616124
	29430610758									7213011731
										6730784873
										33866524935
										3977560878
										5143786312
										5318268259
										5390865451
										6776164077
										5026497483
										4780878969
										4967450451
										5361268219
										5943380886

										7183313913
										33882235763
										5769615899
										6308639476
										5653580861
										33238374889
										4939841148
										5114337246
										5289476567
										6442881546
										60317023836
										4181682668
										6936672449
										6789743586
										6469586494
										7008874260
										6119118591
										33822327772
										5581889337
										4530544649
										4822330854
										4704968408
										6106562781

Supplemental Table 2. Identity and primary cilia contactome of all the astrocytes examined in this study (Related to Figures 1 and 7). Astrocyte cell identity numbers with links to their location in Neuroglancer are listed in the ‘Astrocyte Cilia’ column for astrocytes from all 6 cortical layers. For the same astrocytes, cell identity numbers with links to electron micrographs and 3D images showing all the contacting cells of the respective astrocyte cilium is listed in the ‘Astrocyte Cilia Connectome’ column.

Table 2. Astrocyte primary cilia and their contactome

Astrocytes with Primary Cilia and all the Ciliary Contacts											
Layer 1		Layer 2		Layer 3		Layer 4		Layer 5		Layer 6	
Astrocyte Cilia	Astrocyte Cilia Contactome	Astrocyte Cilia	Astrocyte Cilia Contactome	Astrocyte Cilia	Astrocyte Cilia Contactome	Astrocyte Cilia	Astrocyte Cilia Contactome	Astrocyte Cilia	Astrocyte Cilia Contactome	Astrocyte Cilia	Astrocyte Cilia Contactome
27276159469	27276159469	39883406745	39883406745	3794946757	3794946757	33345021009	33345021009	33300852724	33300852724	48842084242	48842084242
29461068729	29461068729	1595334968	1595334968	30769638357	30769638357	5947996093	5947996093	6732492658	6732492658	6365862641	6365862641
4191802393	4191802393	28002457747	28002457747	49111238669	49111238669	3151320456	3151320456	4254148518	4254148518	6875714865	6875714865
36505290510	36505290510	20287900622	20287900622	4114811800	4114811800	32646042076	32646042076	31289930813	31289930813	13672990759	13672990759
1845611102	1845611102	19851388892	19851388892	4186297069	4186297069	50202167064	50202167064	4299324693	4299324693	15027905094	15027905094
942890416	942890416	36359266866	36359266866	1957206767	1957206767	50159210166	50159210166	5245001252	5245001252	15348601268	15348601268
2835369600	2835369600	46477160160	46477160160	2104764597	2104764597	20503148746	20503148746	29933994251	29933994251	15712108514	15712108514
6127763803	6127763803	766261797	766261797	2308477723	2308477723	21389823581	21389823581	30938572279	30938572279	22902107816	22902107816
27363458847	27363458847	10285821245	10285821245	2642884622	2642884622	29470353717	29470353717	7052576523	7052576523	23995591198	23995591198
27406896586	27406896586	28323985234	28323985234	2672406452	2672406452	32573634999	32573634999	30808448317	30808448317	24243515825	24243515825
27450642099	27450642099	37143792449	37143792449	2686453762	2686453762	33068872479	33068872479	32410030863	32410030863	24461202084	24461202084
27858243806	27858243806	19967218698	19967218698	3357866345	3357866345	12758997233	12758997233	33867883022	33867883022	24475905560	24475905560
35864832353	35864832353	46841046168	46841046168	3546496571	3546496571	30882721268	30882721268	6572539053	6572539053	22946450584	22946450584
44671715836	44671715836	2193552394	2193552394	3924545503	3924545503	56474333357	56474333357	23341407780	23341407780	23135606862	23135606862
36330590381	36330590381	28950018435	28950018435	4027146800	4027146800	3179500405	3179500405	24303657137	24303657137	5170901819	5170901819
36214409458	36214409458	12354768601	12354768601	4435419981	4435419981	21406293541	21406293541	30983761968	30983761968	31010554402	31010554402
36287210816	36287210816	1960725824	1960725824	4769198763	4769198763	29352918184	29352918184	23415624943	23415624943	4895263796	4895263796
28164470134	28164470134	36618622440	36618622440	4872237836	4872237836	5830940247	5830940247	32440663633	32440663633	31213376244	31213376244
28572086994	28572086994	36502209598	36502209598	5031870634	5031870634	31567290550	31567290550	33066681713	33066681713	31287127411	31287127411
28615831655	28615831655	38078271648	38078271648	5295039274	5295039274	46821217277	46821217277	13892020405	13892020405	31592317609	31592317609
28513931599	28513931599	50379993164	50379993164	5337148218	5337148218	21463850566	21463850566	23340867567	23340867567	31970964596	31970964596
28601332813	28601332813	1347790212	1347790212	5934869602	5934869602	3280714280	3280714280	31085603325	31085603325	13425357975	13425357975
28455688239	28455688239	57978864084	57978864084	38819753295	38819753295	32747372611	32747372611	13281041592	13281041592	51859117906	51859117906
5458411035	5458411035	28147984357	28147984357	5090434903	5090434903	39982416172	39982416172	30227007194	30227007194	4879918613	4879918613
1931772020	1931772020	1448756332	1448756332	39431199514	39431199514	32034917021	32034917021	13340993451	13340993451	14824061607	14824061607
27917728129	27917728129	67411504028	67411504028	3808320466	3808320466	77701850842	77701850842	15451553143	15451553143	49104784400	49104784400
1015500235	1015500235	4188823663	4188823663	4216331025	4216331025	69068644667	69068644667	13892910977	13892910977	14371181153	14371181153
3419409575	3419409575	32780327740	32780327740	1724685590	1724685590	72674433698	72674433698	69488715150	69488715150	41799189766	41799189766
45298815639	45298815639	31236460345	31236460345	1842441790	1842441790	2989599124	2989599124	30457426061	30457426061	68439414719	68439414719
54616021548	54616021548	46300867516	46300867516	2452969442	2452969442	55788625288	55788625288	78136960334	78136960334	5258521005	5258521005
54688689312	54688689312	1072167654	1072167654	2657339348	2657339348	49910176430	49910176430	48189025135	48189025135	4895220614	4895220614
54892723169	54892723169	459787015	459787015	2700149400	2700149400	29730193056	29730193056			5651784707	5651784707
55431530004	55431530004					76185507552	76185507552			5870405391	5870405391
81254771166	81254771166									6847610055	6847610055
535055035	535055035									13832215106	13832215106
679706355	679706355									23893179489	23893179489
811932440	811932440										
1481125634	1481125634										

Supplemental Table 3. Construction of neuronal primary cilia contactome (Related to Figures 1, 2, 3, 5, and 6). Neuronal cell identity numbers with links to electron micrographs and 3D images showing all the contacting cells of the respective neuronal cilium. These are the same neurons with primary cilia listed in Table 1.

Table 3. Cortical neuronal primary cilia and their contactome

Interneurons with Primary Cilia and all the Ciliary Contacts						Projection Neurons with Primary Cilia and all the Ciliary Contacts				
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6
37146142910	2718663948	4638898421	32791599134	6165551025	33516085703	1450376143	3387696184	29193343834	6513769803	5015430105
1787105373	2120678770	4275786135	32661562811	4840261666	6017103252	2602073423	2542472136	6864952954	6907908318	5012275127
2137208420	3125257652	3882494653	3995330445	3630670085	39962851803	1144733018	3925990067	32370126505	5422636543	4196721639
3680606691	3505468100	5309538535	5190802710	3891078930	33866261968	3518798548	3590955885	32194884853	6077169826	4650667613
37263286765	30202520112	6270371417	33331734971	4198064933	5521456474	1087542412	3562439721	4302872019	7052633592	6382769913
1190245536	1451297107	38658046334	56268867905	4476359994	6570362443	31046662942	2702674358	4913528885	4691667594	6981906973
1394191353	3198787432	2351346522	3456758527	4679607351	6717175479	2091155727	5075775279	5075322225	5918005808	33471670504
3113022318	4946396640	3515979249	3531238060	5566456712	5580327531	2280501088	2629407821	5482019597	3120073110	4604762284
3156431067	30187598118	4858659202	4679722794	6544359249	34230002763	3722481176	2629129838	6326350514	3528902155	5348331739
4409589695	58560947015	30624168062	4756145379	6879101098	4472579416	3140018733	3459620418	6500949268	5581378299	7285402573
1423553872	58663315438	32444504548	5220472240	7039231083	5492502881	3402471987	4841385043	6677125078	4094208392	5273488042
1452668296	1130278365	37522862988	5453255395	31230444707	7401757982	3489216996	5075979625	3878288639	4215470603	6292434122
1729080661	1449763370	39547803419	5612478783	42428944531		2105961568	2993570100	4011683186	4415590654	4997922584
2005856933	1858285103	2031190321	2844816353	3165277795		30742013887	4306756083	4624107703	5900936104	4997353939
3360318069	2338920806	3605090256	3458174974	5335761695		1596327698	3358492873	5860360217	33693108475	5141786988
3403480065	2907424570	5061116204	3588896643	5814600156		1728497220	3852445941	32007131507	4389878275	5390718424
36330415163	2979713896	5177967272	3866563836	6340396662		1886902875	4450399407	3020714778	4492479490	5975007104
636444441	3359150816	5469125788	4491632837	6747400414		1931040660	2761371616	3399332888	4722533363	6410715337
3301154728	3636599493	32370272208	4856468392	33737933543		2950834375	2860905618	3529456529	4939724073	31708920904
4627598544	1801310916	32371237036	5146312557	4910564616		3256534868	3183397934	5380337105	5352771787	6904345674
38485858513	5384426784	39428921609	6121790491	4111160213		4363495628	3517950418	6342515021	6456401608	4706559981
460458122	5733156051	41819250669	13910213238	5887343270		2178659041	4741455769	32413053449	4197890854	5726746103
533711979	29459622174	41995120012	30372826830	6601988172		4800503033	5163674335	33170917656	4519330988	5841641104
1613060545	37581631856	1245656455	31568253559	33677281270		1522022884	5849014680	33184336456	5598008907	39714911298
402243212	37787097036	4361422065	38598226398	41902636649		2484316542	6067314832	2786572808	5872566163	5055406469
36942459652	38761962949	4624939761	38918762655	69358211160		2485369079	3430549988	3180420219	30036113523	5272919263
37452370153	38878740946	4902169919	40578793854	5159191086		3460232910	3882785546	3208569762	32837446270	5959209063
5005850706	40320605179	5687893999	42138312710	4139325860		3518681641	2484069388	3923858755	4241562819	6162731760
36534317289	45617277589	5965472721	2742433932	4561615237		1392936586	2498888339	4157284371	5276699233	6251229281
36621675715	45878986196	6430938176	3135331454	6107131430		3097120902	3298206355	4404218019	4054800495	30995793577
57352977341	2369144469	29383098617	4302346100	6121834307		28717044681	4028123903	4535129012	3922677106	32874985597
53711736279	2587780387	29996426864	4710473618	4300856796		30538009064	5438945541	5891606808	6848234050	5216105078
1918849113	3504882559	32006576283	5817331865	5131492402		31557144036	2933472324	5931875589	4592526340	5754239725

520117544	36882405719	37113947425	32180430283	5188348808		1901152704	5689193184	3749127975	5159993420	6381703408
38034714996	40218295373	38585771987	33418434625	5335030417		39112226336	852830461	3254783068	3222499167	5216747637
45021732268	4043892994	1886245145	37970340183	4737485281		36533601596	4406450407	3922442762	5654092357	5234152619
4380314835	5164550020	2366705935	37985028964	4343419233		28571136739	2789944495	3998937770	5799532727	5189021397
3594737701	37786221088	32588893142	39879625402	42529034364		36138629591	2307965742	4695405082	3008550652	5389697163
4002616369	30551674827	38804992102	51426052246	4489384273		37976035229	3809752632	4753414558	5917684171	5668839584
491470940	5908382258	5453780789	3530406006	6660510250		27667130272	4930830982	4899818199	5814309652	31419410828
1730029758	37262192364	4363436095	40958245296	3658558300		3111531808	2351622488	5104816512	3443968258	4210329807
1263103927	2616018803	4930116577	42225990497	3325450780		2675269381	3168855453	5132280723	4197686564	31460631882
3521018165	4568230875	5629853784	2728344352	5393507695		4830040033	1667872789	5935014505	2872995228	6105802392
2138112811	29139188774	32444357870	13092966158	3498414218		2077460715	3897139701	6007246666	3745551509	33953035801
2167328640	2659353359	41644462221	30913165738	6165009450		3578646904	3256008975	6328015219	4853649886	4472068090
55766359917	1480119406	41265450123	3807269209	67494392965		3824820293	5425833823	4462751886	6325270042	6571050167
695140502	36938079094	3953616201	29250930372	4561571429		29110569948	4552416806	4374709076	6425769635	7516202205
343606869	2557789796	3735023422	5248344086	6265684619		2601212268	2863184351	5861148055	6354268105	23921710148
359185130	2324932486	6255244644	32836028865	38740557584		2485090217	2396754193	2030050061	4475878153	30923589906
5472060932	925485691	2497121775	2713962340	25220483055		1989663691	4289131873	5117358943	7081689438	6278999548
	1069962332	3458613090	37882747944	6500176105		4713684670	5353501752			33546616234
	2470373696	42256916348	20864727467			5718116647	4479995708			5184873511
	3214192411	65019948281	31991127834			1843099641	3167438862			5462089350
	49390132072	29835261616	3805153314			4845941742	4319925653			6718066168
	40640688374	59885243362	6721015852			2456488265	4538560279			5898892521
	48807815597	3181937794	64478586301							4476038951
	882090316	2846816391	6779098861							4998273531
	1333290325	41440369640								6426367387
	1887575004	38527617086								6556053420
	39767314376									6584686007
	1727591544									6731470222
	40742704980									7079616124
	29430610758									7213011731
										6730784873
										33866524935
										3977560878
										5143786312
										5318268259
										5390865451

										6776164077
										5026497483
										4780878969
										4967450451
										5361268219
										5943380886
										7183313913
										33882235763
										5769615899
										6308639476
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										33238374889
										4939841148
										5114337246
										5289476567
										6442881546
										60317023836
										4181682668
										6936672449
										6789743586
										6469586494
										7008874260
										6119118591
										33822327772
										5581889337
										4530544649
										4822330854
										4704968408
										6106562781

Supplemental Table 4. Comparison of the average number of contacts (cell types) made by a neuronal cilium (IN or PN) and an adjacent axonal segment of similar size (Related to Figures 5, 6, and S4). IN, interneuron; PN, projection neuron. L1-L6, cortical layers. Data shown are mean ± SEM.

Table 4

	Cell Types	L1		L2		L3		L4		L5		L6	
		Cilium	Axon	Cilium	Axon	Cilium	Axon	Cilium	Axon	Cilium	Axon	Cilium	Axon
IN Cilia	Interneurons	12.4 ± 0.93	6.8 ± 0.68	12.8 ± 0.92	6.85 ± 0.98	12.6 ± 0.77	14.4 ± 1.31	11.9 ± 0.69	12.4 ± 0.83	9 ± 0.60	10.6 ± 0.98	10.3 ± 1.73	7.9 ± 1.4
	Projection neurons	17 ± 0.92	18.2 ± 1.83	21.5 ± 1.07	22.9 ± 2.01	19.6 ± 1.12	21.15 ± 1.73	17.6 ± 0.95	18.8 ± 1.09	15.6± 0.91	17.3 ± 1.01	15.9 ± 2.14	20 ± 3.7
	Astrocytes	2.40± 0.17	1.65 ± 0.22	1.79 ± 0.11	1.25 ± 0.19	1.71 ± 0.09	1.95 ± 0.34	2.07 ± 0.12	1.7 ± 0.24	1.39 ± 0.09	1.5 ± 0.22	1.42 ± 0.25	1.14 ± 0.26
	Oligodendrocytes	0.08 ± 0.04	0.05 ± 0.05	0.02 ± 0.02	0	0.07 ± 0.03	0.02 ± 0.09	0.14 ± 0.05	0.2 ± 0.09	0.16 ± 0.05	0.1 ± 0.08	0.08 ± 0.08	0
	Microglia/OPCs	0.22 ± 0.07	0	0.19 ± 0.05	0.15 ± 0.08	0.05 ± 0.03	0.05 ± 0.05	0.12 ± 0.07	0	0.10 ± 0.04	0.15 ± 0.08	0.08 ± 0.08	0
	Blood vessels	0	0	0	0	0	0	0	0	0	0	0	0
	Undefined	7.42± 0.37	4.95 ± 0.31	7.73 ± 0.33	3.45± 0.36	9.58 ± 0.48	3.75± 0.34	11.50± 0.55	7.5 ± 0.72	10.0 ± 0.45	5.5 ± 0.39	10.3 ± 1.15	6.13± 0.61
PN Cilia	Interneurons			4.33 ± 0.29	9.5 ± 0.8	6.24 ± 0.37	9.45 ± 0.77	6.96 ± 0.52	8.40 ± 0.99	5.50 ± 0.42	8.1 ± 0.57	5.42 ± 0.26	6.25 ± 0.46
	Projection neurons			40.0 ± 1.38	21.6 ± 1.66	36.3 ± 1.42	19.5 ± 1.90	29.7 ± 1.44	17.2 ± 1.38	24.8 ± 1.19	18 ± 1.79	19.4 ± 0.87	14.1 ± 1.27
	Astrocytes			2.49 ± 0.13	1.6 ± 0.23	2.27 ± 0.14	1.65 ± 0.27	2.58 ± 0.16	1.55± 0.25	1.78 ± 0.12	1.35 ± 0.22	1.63 ± 0.08	0.65 ± 0.15
	Oligodendrocytes			0.11 ± 0.04	0.05 ± 0.06	0.13 ± 0.05	0.05 ± 0.05	0.14 ± 0.06	0.2 ± 0.09	0.18 ± 0.07	0.05 ± 0.06	0.17 ± 0.05	0.3 ± 0.11
	Microglia/OPCs			0.18 ± 0.05	0.05 ± 0.06	0.18 ± 0.06	0.15 ± 0.08	0.04 ± 0.03	0.05 ± 0.06	0.14 ± 0.05	0.05 ± 0.08	0.10 ± 0.03	0.1 ± 0.08
	Blood vessels			0	0	0	0	0	0	0	0	0	0
	Undefined			9.91± 0.43	5.25 ± 0.3	8.89 ± 0.41	5.10 ± 0.36	8.88 ± 0.40	6.50 ± 0.41	12.1 ± 0.55	6.90 ± 0.54	12.0 ± 0.40	6.95 ± 0.85

Two-way ANOVA (cell types, IN_{cilia} versus IN_{axon}): L1 ($p=1.9E^{-4}$), L2 ($p=1.74E^{-4}$), L3 ($p=1.5E^{-4}$), L4 ($p=2E^{-5}$), L5 ($p=1.6E^{-4}$), L6 ($p=5.1E^{-4}$).
Two-way ANOVA (cell types, PN_{cilia} versus PN_{axon}): L2 ($p=9.7E^{-3}$), L3 ($p=1E^{-2}$), L4 ($p=4.6E^{-3}$), L5 ($p=7.2E^{-4}$), L6 ($p=5.6E^{-4}$).

Supplemental Table 5. Comparison of the average number of contacts (cell domains) made by a neuronal cilium (IN or PN) and an adjacent axonal segment of similar size (Related to Figures 5, 6, and S4). IN, interneuron; PN, projection neuron. L1-L6, cortical layers. Data shown are mean ± SEM.

Table 5

	Cell Domains	L1		L2		L3		L4		L5		L6	
		Cilium	Axon	Cilium	Axon	Cilium	Axon	Cilium	Axon	Cilium	Axon	Cilium	Axon
IN Cilia	Inhibitory axons	12.0 ± 1.09	6.1 ± 0.81	12.5 ± 1.01	6.4 ± 1	12.5 ± 0.96	13.8 ± 1.75	11.6 ± 0.89	11.9 ± 1.45	8.75 ±0.72	10 ± 1.29	10.3 ± 1.94	7.7 ± 1.80
	Excitatory axons	14.2 ± 1.17	15.8 ± 2.1	18.7 ± 1.33	20.2 ± 2.58	17.4 ± 1.32	18.3 ± 2.33	16.1 ± 1.19	17.4 ± 2.04	14.5 ± 1.13	16 ± 1.90	14.8 ± 2.52	18.9 ± 4.31
	Inhibitory dendrites	0.44 ± 0.10	0.70 ± 0.15	0.25 ± 0.07	0.45 ± 0.14	0.25 ± 0.07	0.3 ± 0.15	0.25 ± 0.06	0.25 ± 0.09	0.24 ± 0.07	0.6 ± 0.17	0	0.14 ± 0.14
	Excitatory dendrites	2.86 ± 0.26	2.45 ± 0.45	2.75 ± 0.23	2.65 ± 0.46	2.15 ± 0.20	2.25 ± 0.39	1.49 ± 0.17	1.35 ± 0.23	1.08 ± 0.17	1.15 ± 0.22	1.17 ± 0.32	1 ± 0.38
	Cilia	0	0	0	0	0	0	0	0	0	0	0	0
	AIS	0	0	0	0	0	0	0	0	0	0	0	0
	Soma	0	0	0.02 ± 0.02	0	0.05 ± 0.03	0.05 ±0.05	0	0	0.02 ± 0.02	0	0	0.14 ± 0.38
	Astrocyte processes	2.40 ± 0.17	1.65 ± 0.22	1.79 ± 0.11	1.25 ± 0.19	1.71 ± 0.09	1.95 ± 0.34	2.07 ± 0.12	1.7 ± 0.24	1.39 ± 0.09	1.5 ± 0.22	1.42 ± 0.25	1.14 ± 0.26
	Oligodendrocyte processes	0.08 ± 0.04	0.05 ± 0.05	0.02 ± 0.02	0	0.07 ± 0.03	0.20 ±0.09	0.14 ± 0.05	0.2 ± 0.09	0.16 ± 0.05	0.1 ± 0.08	0.08 ± 0.08	0
	Microglia/OPC processes	0.22 ± 0.07	0	0.19 ± 0.05	0.15 ± 0.08	0.05 ± 0.03	0.05 ±0.05	0.12 ± 0.07	0	0.10 ± 0.04	0.15 ± 0.08	0.08 ± 0.08	0
	Undefined	7.42 ± 0.37	4.95 ±0.31	7.73 ± 0.33	3.45 ±0.36	9.58 ± 0.48	3.75 ± 0.34	11.5 ±0.55	7.55 ± 0.72	10.0 ± 0.45	5.5 ± 0.39	10.3 ± 1.15	6.13 ± 0.61
PN Cilia	Inhibitory axons			3.96 ± 0.34	9.15 ± 1.18	6.04 ± 0.47	9.05 ±1.15	6.72 ± 0.59	8.35 ±1.13	5.06 ± 0.46	7.65 ± 0.51	5.27 ± 0.32	6.20 ± 0.75
	Excitatory axons			36.4 ± 2.61	18.8 ± 2.37	34.0 ± 2.47	17.9 ±2.35	28.2 ± 2.17	15.4 ±1.88	23.5 ± 1.82	16.9 ± 2.21	18.1 ±1.06	12.9 ±1.67
	Inhibitory dendrites			0.36 ± 0.08	0.4 ± 0.11	0.20 ± 0.07	0.4 ± 0.11	0.24 ± 0.07	0.55 ± 0.17	0.44 ± 0.08	0.40 ± 0.12	0.15 ±0.04	0.05 ± 0.07
	Excitatory dendrites			3.56 ± 0.30	2.8 ± 0.37	2.31 ± 0.23	1.65 ± 0.35	1.54 ± 0.23	1.75 ± 0.32	1.28 ± 0.16	1 ± 0.26	1.33 ±0.13	1.1 ± 0.02
	Cilia			0	0	0	0	0	0	0	0	0	0
	AIS			0	0	0	0	0	0	0	0	0	0
	Soma			0	0	0	0	0	0	0	0	0	0
	Astrocyte processes			2.49 ± 0.13	1.6 ± 0.23	2.27 ± 0.14	1.65 ± 0.27	2.58 ± 0.16	1.55 ± 0.25	1.78 ± 0.12	1.35 ± 0.22	1.63 ± 0.08	0.65 ± 0.15
	Oligodendrocyte processes			0.11 ± 0.04	0.05 ± 0.06	0.13 ± 0.05	0.05 ± 0.05	0.14 ± 0.06	0.2 ± 0.09	0.18 ± 0.07	0.05 ± 0.06	0.17 ± 0.05	0.3 ± 0.11
	Microglia/OPC processes			0.18 ± 0.05	0.05 ± 0.06	0.18 ± 0.06	0.15 ± 0.08	0.04 ± 0.03	0.05 ± 0.06	0.14 ± 0.05	0.05 ± 0.08	0.10 ± 0.03	0.1 ± 0.08
	Undefined			9.91 ± 0.43	5.25 ±0.30	8.89 ± 0.41	5.10 ± 0.36	8.88 ± 0.40	6.50 ±0.41	12.1 ± 0.55	6.90 ± 0.54	12.0 ± 0.40	6.95 ± 0.85

Two-way ANOVA (cell domains, IN_{cilia} versus IN_{axon}): L1 ($p=7.6E^{-7}$), L2 ($p=4.4E^{-6}$), L3 ($p=7.61^{E-7}$), L4 ($p=2.6^{E-7}$), L5 ($p=6.3E^{-7}$), L6 ($p=3.3E^{-6}$).
Two-way ANOVA (cell domains, PN_{cilia} versus PN_{axon}): L2 ($p=1E^{-3}$), L3 ($p=7E^{-4}$), L4 ($p=1E^{-4}$), L5 ($p=1.3E^{-5}$), L6 ($p=1.2E^{-5}$).

Supplemental Table 6. Construction of control axon segment contactome (Related to Figures 5, 6, and S4). Neuronal cell identity numbers with links to electron micrographs and 3D images showing all the contacting cells of the neuronal cilia and respective control axon segments.

Table 6. Control Axon Segment Contactome of Neurons with Primary Cilia

Interneurons with Primary Cilia											
Layer 1		Layer 2		Layer 3		Layer 4		Layer 5		Layer 6	
Neuronal Cilia Contactome	Corresponding Control Axonal Contactome	Neuronal Cilia Contactome	Corresponding Control Axonal Contactome	Neuronal Cilia Contactome	Corresponding Control Axonal Contactome	Neuronal Cilia Contactome	Corresponding Control Axonal Contactome	Neuronal Cilia Contactome	Corresponding Control Axonal Contactome	Neuronal Cilia Contactome	Corresponding Control Axonal Contactome
636444441	927661587	36882405719	36984275898	5309538535	40202702204	5190802710	22979595092	4198064933	39848524614	32350764963	85397206542
36942459652	37160889888	30202520112	39140522553	38658046334	39167782758	56268867905	73650336571	7039231083	51249817963	33516085703	77508401986
402243212	562680145	30187598118	30144072998	4858659202	5019021852	3456758527	11972922760	31230444707	49280800074	4472579416	4486960460
3827141391	3870901495	882090316	750988259	39428921609	39283597458	4679722794	13632560397	6165551025	6470930224	5492502881	5870566564
37146142910	46011271164	1130278365	1712478325	3882494653	4028388070	4756145379	40827609030	6544359249	6820828406	6017103252	50605564779
1394191353	1510737444	2324932486	2499326947	5177967272	40610099168	5220472240	40608419421	25220483055	25293036262	7401757982	7372702250
5005850706	4976912407	2703113569	2543086577	4902169919	5338754203	5612478783	41962574370	3658558300	12727663117	39962851803	39948294625
3403480065	3112131247	2907424570	3169513309	29383098617	38262973468	2713962340	2873902103	33677281270	42513543563	6570362443	69064935305
3156431067	3229188394	5733156051	5835305206	4361422065	4768964793	2844816353	20531503857	3498414218	12815648416		
3301154728	3316195486	37787097036	47277922691	41995120012	59783678894	3866563836	4681476080	3891078930	4211221864		
3113022318	2938321430	1449763370	10140599358	3515979249	12352139608	32791599134	49968901770	6265684619	41247315456		
1423553872	10216043355	2703113569	2338832361	2031190321	2438441389	5453255395	49517977677	3630670085	48510377424		
2137208420	2093361676	3636599493	3665421460	5061116204	39780673092	29250930372	38189092099	4139325860	4401356111		
4380314835	13231207595	38761962949	38660208804	29835261616	91732389217	31991127834	40827376640	41902636649	50855327555		
1190245536	9909773433	40218295373	66959778246	41819250669	42256215808	3588896643	4010792627	6879101098	15977423010		
4409589695	4409561571	2718663948	2849707822	38585771987	38600314583	3531238060	4142158194	4300856796	4547847232		
1452668296	10507421020	2338920806	2600935439	4275786135	4653996159	42225990497	51309784422	4561571429	4634256070		
5472060932	5442363080	5384426784	5340609135	5687893999	5877078075	30913165738	66418387824	6107131430	76985686680		
2005856933	19183583614	45617277589	36897458288	4930116577	49343467409	3807269209	57465813662	33737933543	42763001264		
36534317289	36636335092	5908382258	6082937865	41644462221	59346173893	64478586301	73212977850	5814600156	41873026181		

Projection Neurons with Primary Cilia									
Layer 2		Layer 3		Layer 4		Layer 5		Layer 6	
Neuronal Cilia Contactome	Corresponding Control Axonal Contactome	Neuronal Cilia Contactome	Corresponding Control Axonal Contactome	Neuronal Cilia Contactome	Corresponding Control Axonal Contactome	Neuronal Cilia Contactome	Corresponding Control Axonal Contactome	Neuronal Cilia Contactome	Corresponding Control Axonal Contactome
27667130272	62764778482	3562439721	3488923980	29193343834	37505269371	3222499167	21753782928	33882235763	96229278820
1450376143	37537902326	3925990067	39474856573	6864952954	68529707332	4691667594	57054416102	4196721639	66704523434
2602073423	20856871571	3256008975	3576691128	4913528885	40244358823	5918005808	6530006788	4604762284	40808117188
2105961568	37684014334	5425833823	67381367053	5075322225	67714167609	4094208392	39482873037	5348331739	5973065160
1728497220	11539229244	4552416806	22530585154	2030050061	3266770115	3120073110	39265741389	6789743586	6949800155
3518681641	55880627201	3167438862	38687162227	3180420219	20881898351	30036113523	74129935368	5141786988	75685861997
31557144036	58255026737	3852445941	48616687884	3254783068	39166716492	4415590654	75469035951	5390718424	40720570468
36138629591	53810862022	4289131873	75358200612	3998937770	50128840915	3222499167	4358034003	6410715337	15407224373
3111531808	21220714399	2498888339	47291005238	4753414558	4855344413	4241562819	39936642802	6251229281	94874101195
2485369079	11903071975	2484069388	37916243201	5891606808	50391103435	4853649886	5451240280	6162731760	41828114513
3460232910	65314376370	4930830982	57234927825	5931875589	41729513545	5276699233	49501785139	32874985597	42541504276
30538009064	65824710849	4930830982	40421498213	4695405082	4797115109	6907908318	69212202042	6981906973	78177944808
36533601596	45937813387	4306756083	13694847565	4753414558	31349369666	3443968258	83870671575	5273488042	40735520846
37976035229	64659273541	2761371616	3562178017	6328015219	6647559153	33693108475	69285498345	6292434122	41113102769
3722481176	48122444072	5438945541	40958683532	2786572808	11826562669	6513769803	42397377553	6119118591	24665572283
3489216996	47321389715	852830461	1652804530	5860360217	50201844795	6077169826	41538604967	6571050167	7007327151
1931040660	37742009306	4406450407	75489360641	33170917656	60144833926	4939724073	5187005454	5012275127	5477711888
28571136739	72693955177	3517950418	48121859765	3208569762	56517025462	5917684171	6369176577	6904345674	59936711502
4845941742	5922473227	6067314832	50175608232	5117358943	66956390277	3745551509	4124944440	6381703408	6817821436
2950834375	55764519447	5689193184	6402276505	6007246666	6254279989	4054800495	66606010902	3977560878	13541888205

Supplemental Table 7. Construction of AIS contactome (Related to Figures 5, 6, and S4). Neuronal cell identity numbers with links to electron micrographs and 3D images showing all the contacting cells of the neuronal cilia and respective AIS.

Table 7. Control Axon Initial Segment (AIS) Contactome of Neurons with Primary Cilia

Interneurons with Primary Cilia		Projection Neurons with Primary CIlia	
Layer 1		Layer 6	
Neuronal Cilia Contactome	Corresponding Control AIS Contactome	Neuronal Cilia Contactome	Corresponding Control AIS Contactome
460458122	460458122	6904345674	6904345674
1190245536	1190245536	5726746103	5726746103
1423553872	1423553872	5055406469	5055406469
1613060545	1613060545	31460631882	31460631882
1787105373	1787105373	33953035801	33953035801
3301154728	3301154728	5216747637	5216747637
4627598544	4627598544	33866524935	33866524935
3113022318	3113022318	7079616124	7079616124
1263103927	1263103927	6730784873	6730784873
1730029758	1730029758	6718066168	6718066168

Supplemental Table 8. (A) Comparison of the average number of contacts (cell types) made by the neuronal cilia (interneuronal [L1] or projection neuronal [L6]) and the AIS of the respective neurons. Data shown are mean ± SEM. **(B) Comparison of the average number of contacts (cell domains) made by the neuronal cilia (interneuronal [L1] or projection neuronal [L6]) and the AIS of the respective neurons.** Data shown are mean ± SEM. (Related to Figures 5, 6, and S4).

Table 8

A

Cell Types	L1 (IN)		L6 (PN)	
	Cilium	AIS	Cilium	AIS
Interneurons	12.4 ± 0.93	21.5 ± 3.18	5.42 ± 0.26	15.2 ± 1.5
Projection neurons	17.0 ± 0.92	26.5 ± 4.9	19.4 ± 0.87	17.2 ± 1.9
Astrocytes	2.40 ± 0.17	4.7 ± 0.34	1.63 ± 0.08	2.7 ± 0.31
Oligodendrocytes	0.08 ± 0.04	0.2 ± 0.13	0.17 ± 0.05	0.2 ± 0.13
Microglia/OPCs	0.22 ± 0.07	0.2 ± 0.13	0.10 ± 0.03	0.1 ± 0.1
Blood vessels	0	0	0	0
Undefined	7.42 ± 0.37	9.7 ± 0.68	12.0 ± 0.40	12.4 ± 1.27

Two-way ANOVA (cell types, IN_{cilia} versus IN_{AIS}): $F_{1,412}$= 30.97, p= $4.7E^{-8}$
Two-way ANOVA (cell types, PN_{cilia} versus PN_{AIS}): $F_{1,755}$= 7.214, p= 0.0074

B

Cell Domains	L1 (IN)		L6 (PN)	
	Cilium	AIS	Cilium	AIS
Inhibitory axons	12.0 ± 1.09	20.8 ± 3.88	5.27 ± 0.32	14.9 ± 2.01
Excitatory axons	14.2 ± 1.17	22 ± 4.57	18.1 ± 1.06	14 ± 1.95
Inhibitory dendrites	0.44 ± 0.10	0.6 ± 0.3	0.15 ± 0.04	0.3 ± 0.15
Excitatory dendrites	2.86 ± 0.26	4.5 ± 0.86	1.33 ± 0.13	3.2 ± 0.76
Cilia	0	0	0	0
AIS	0	0	0	0
Soma	0	0	0	0
Astrocyte processes	2.4 ± 0.17	4.7 ± 0.34	1.63 ± 0.08	2.7 ± 0.31
Oligodendrocyte processes	0.08 ± 0.04	0.2 ± 0.13	0.17 ± 0.05	0.2 ± 0.13
Microglia/OPC processes	0.22 ± 0.07	0.2 ± 0.13	0.10 ± 0.03	0.1 ± 0.1
Undefined cells	7.42 ± 0.37	9.7 ± 0.68	12.0 ± 0.40	12.4 ± 0.87

Two-way ANOVA (cell domains, IN_{cilia} versus IN_{AIS}): $F_{1,648}$= 23.57, p= $1.5E^{-6}$
Two-way ANOVA (cell domains, PN_{cilia} versus PN_{AIS}): $F_{1,1187}$= 5.078, p= 0.024

Supplemental Table 9. (A) The average number of contacts (cell types) made by an astrocyte cilium in different cortical layers. (B) The average number of contacts (cell domains) made by an astrocyte cilium in different cortical layers. L1-L6, cortical layers. Data shown are mean ± SEM. (Related to Figure 7).

Table 9. Contacts (cell types, cell domains) made by an astrocyte cilium in different cortical layers

A

	Cell Types	L1	L2	L3	L4	L5	L6
Astrocyte Cilia	Interneurons	1.89 ± 0.29	1.16 ± 0.30	1.55 ± 0.41	1.03 ± 0.20	1.55 ± 0.33	2.17 ± 0.52
	Projection neurons	5.00 ± 0.61	2.69 ± 0.51	3.00 ± 0.63	2.74 ± 0.44	3.71 ± 0.52	3.72 ± 0.47
	Astrocytes	0.29 ± 0.08	0.28 ± 0.08	0.30 ± 0.08	0.31 ± 0.08	0.13 ± 0.06	0.22 ± 0.07
	Oligodendrocytes	0.03 ± 0.03	0	0.03 ± 0.03	0.03 ± 0.03	0	0.06 ± 0.04
	Microglia/OPCs	0.08 ± 0.04	0	0	0	0	0
	Blood vessels	0	0	0	0	0	0
	Undefined	2.63 ± 0.23	2.03 ± 0.23	1.52 ± 0.15	1.71 ± 0.20	2.77 ± 0.27	2.14 ± 0.19

Two-way ANOVA (cell types, $Astrocyte_{cilia}$ versus IN_{cilia}): $F_{1,76}$= 54.75, p= $1.5E^{-10}$
Two-way ANOVA (cell types, $Astrocyte_{cilia}$ versus PN_{cilia}): $F_{1,69}$= 24.93, p= $4.5E^{-6}$

B

	Cell Domains	L1	L2	L3	L4	L5	L6
Astrocyte Cilia	Inhibitory axons	1.74 ± 0.24	1.09 ± 0.22	1.55 ± 0.32	1.03 ± 0.17	1.52 ± 0.27	2.08 ± 0.41
	Excitatory axons	4.03 ± 0.48	2.31 ± 0.40	2.58 ± 0.46	2.54 ± 0.35	3.45 ± 0.46	3.33 ± 0.40
	Inhibitory dendrites	0.16 ± 0.06	0.06 ± 0.04	0	0	0.03 ± 0.03	0.08 ± 0.05
	Excitatory dendrites	0.97 ± 0.19	0.34 ± 0.10	0.42 ± 0.11	0.17 ± 0.06	0.19 ± 0.07	0.39 ± 0.11
	Cilia	0	0	0	0	0	0
	AIS	0	0	0	0	0.03 ± 0.03	0
	Soma	0	0.03 ± 0.03	0	0.03 ± 0.03	0.03 ± 0.03	0
	Astrocyte processes	0.29 ± 0.08	0.28 ± 0.08	0.30 ± 0.08	0.31 ± 0.08	0.13 ± 0.06	0.22 ± 0.07
	Oligodendrocyte processes	0.03 ± 0.03	0	0.03 ± 0.03	0.03 ± 0.03	0	0.06 ± 0.04
	Microglia/OPC processes	0.08 ± 0.04	0	0	0	0	0
	Undefined cells	2.63 ± 0.23	2.03 ± 0.23	1.52 ± 0.15	1.71 ± 0.20	2.77 ± 0.27	2.14 ± 0.19

Two-way ANOVA (cell domains, $Astrocyte_{cilia}$ versus IN_{cilia}): $F_{1,120}$= 51.95, p= $5.5E^{-11}$
Two-way ANOVA (cell domains, $Astrocyte_{cilia}$ versus PN_{cilia}): $F_{1,109}$= 25.48, p= $1.8E^{-6}$