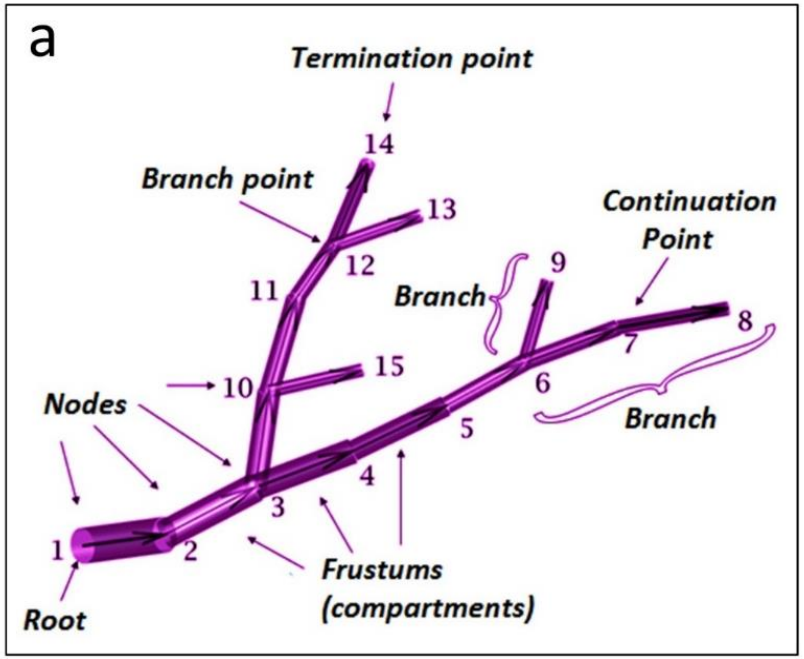
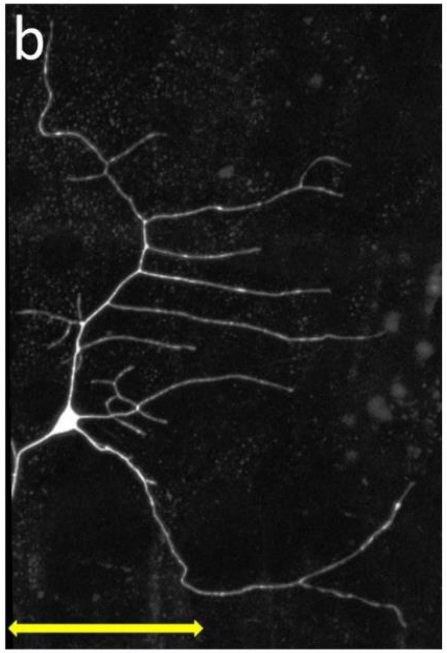
Using a Vaa3D multi-signal plug-in to quantify neuronal cytoskeleton

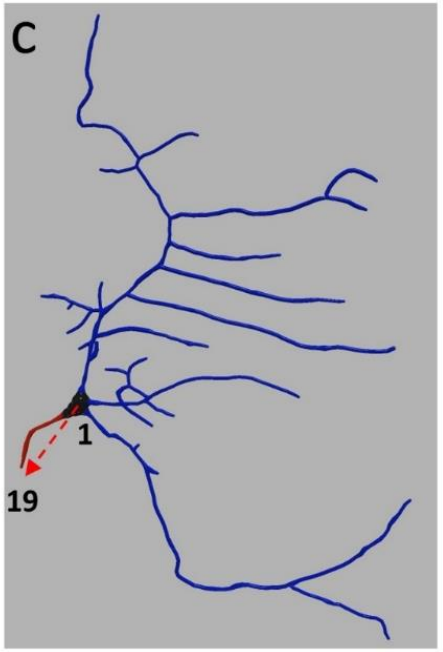
Sumit Nanda

SWC format to describe neuronal morphology

- Morphology data part contains 7 column data positions, each line corresponding to a single neural compartment, with each column separated by blank space.





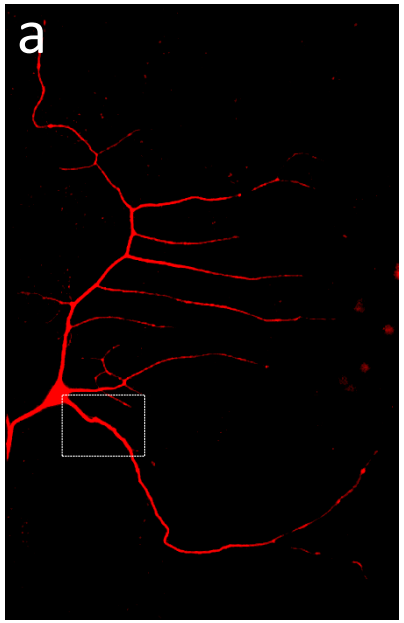


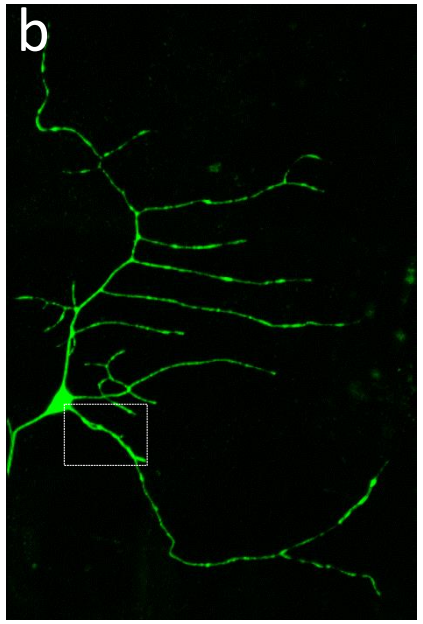
d

Index	Type	X	Y	Z	R	Parent
1	1	279.81	21.61	2.29	2.13	-1
2	1	281.21	23.65	2.26	2.37	1
3	1	282.48	25.27	2.35	3.37	2
4	1	283.60	27.18	2.47	3.86	3
5	1	286.12	27.81	2.48	3.91	4
6	1	288.88	27.73	2.27	2.45	5
7	2	278.16	19.15	2.24	1.30	1
8	2	276.56	16.66	2.18	0.94	7
9	2	274.96	14.16	2.13	0.72	8
10	2	273.48	11.59	2.19	0.84	9
11	2	272.08	8.98	2.18	0.78	10
12	2	270.69	6.36	2.15	0.72	11
13	2	268.68	4.21	2.31	1.05	12
14	2	265.95	3.15	2.28	0.90	13
15	2	263.09	2.38	2.19	1.02	14
16	2	260.14	2.10	2.21	1.05	15
17	2	257.22	1.60	2.19	0.90	16
18	2	254.27	1.36	2.18	0.66	17
19	2	251.36	0.79	2.17	0.59	18

Nanda et al., 2019, Sci Data.

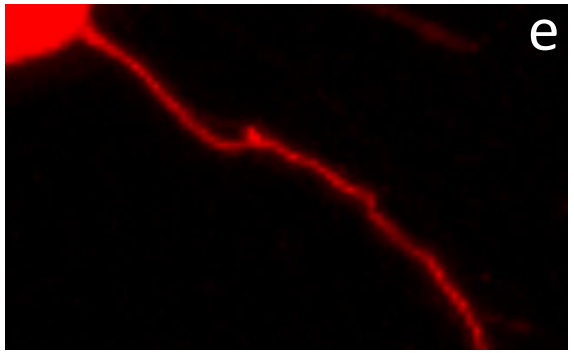
Extension of SWC: Multi-signal neural reconstruction (ESWC)

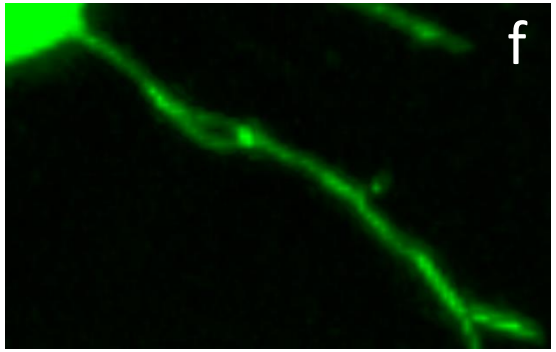


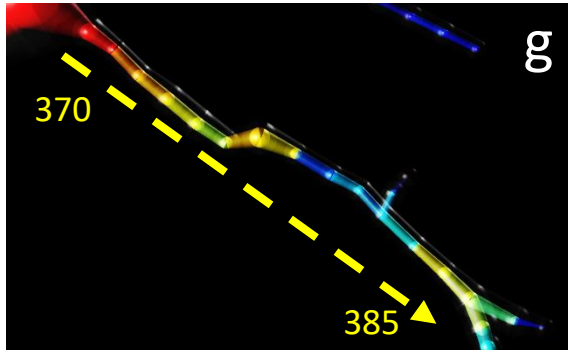


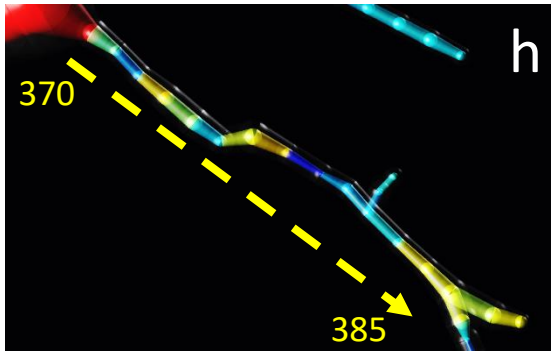
MT

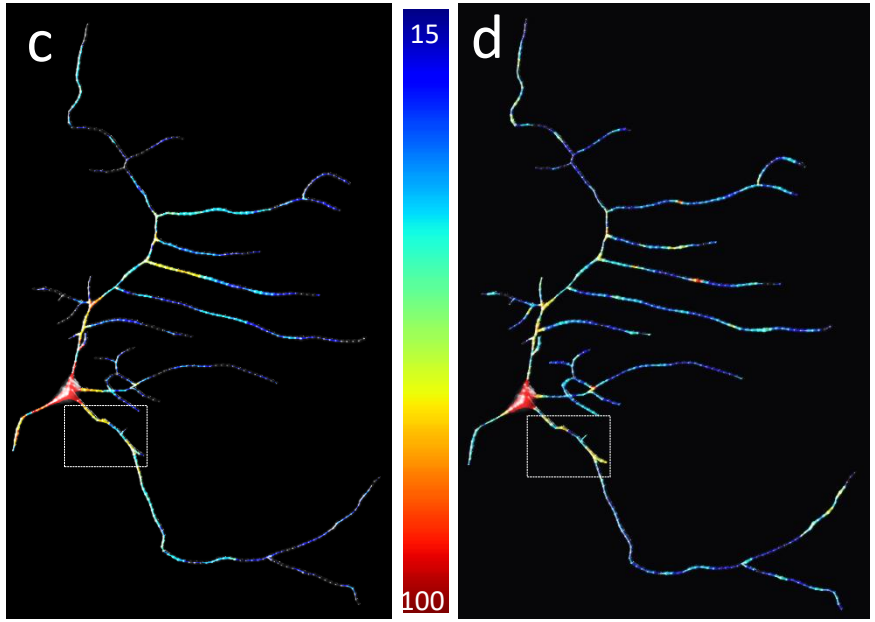
F-actin







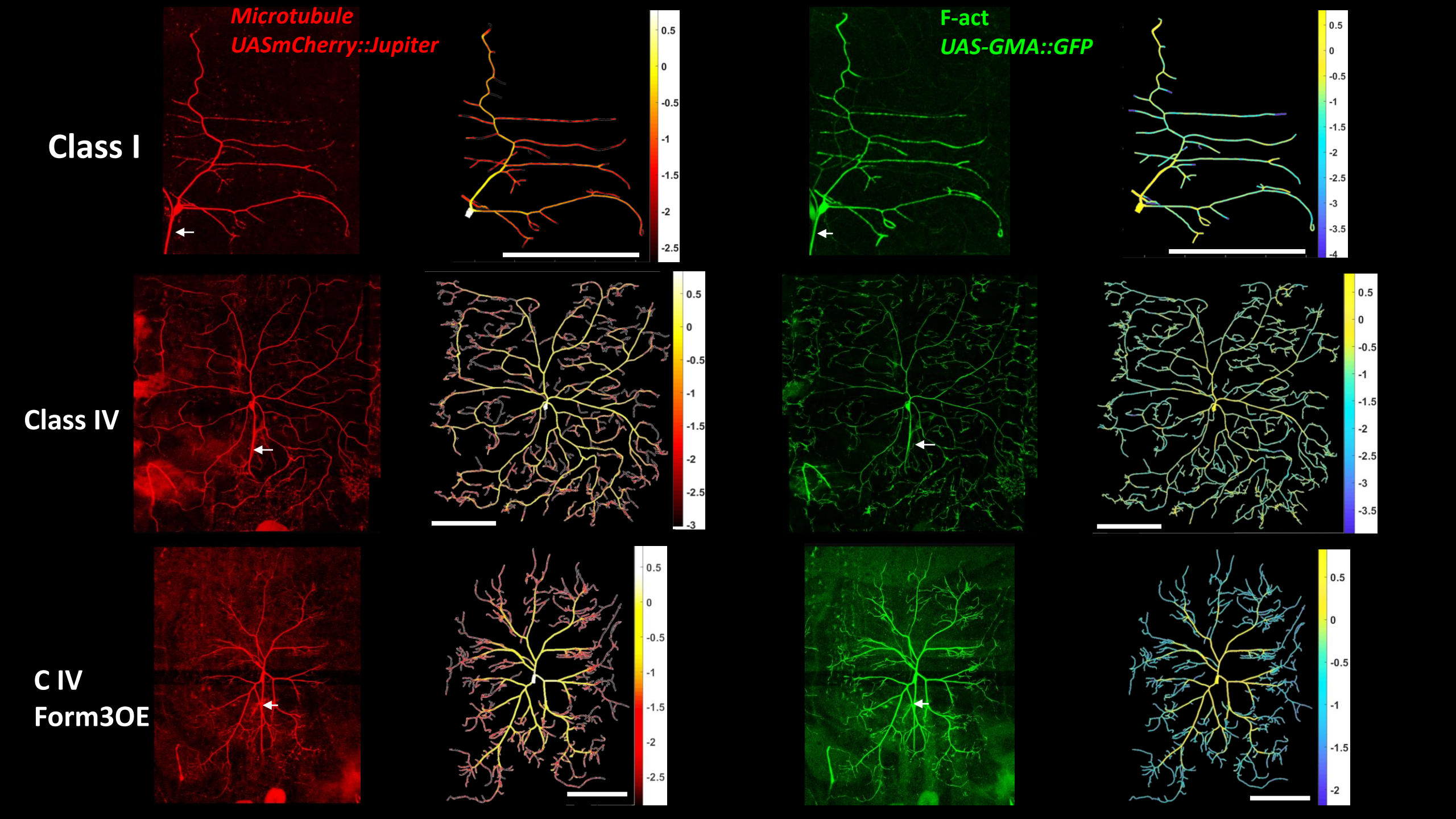




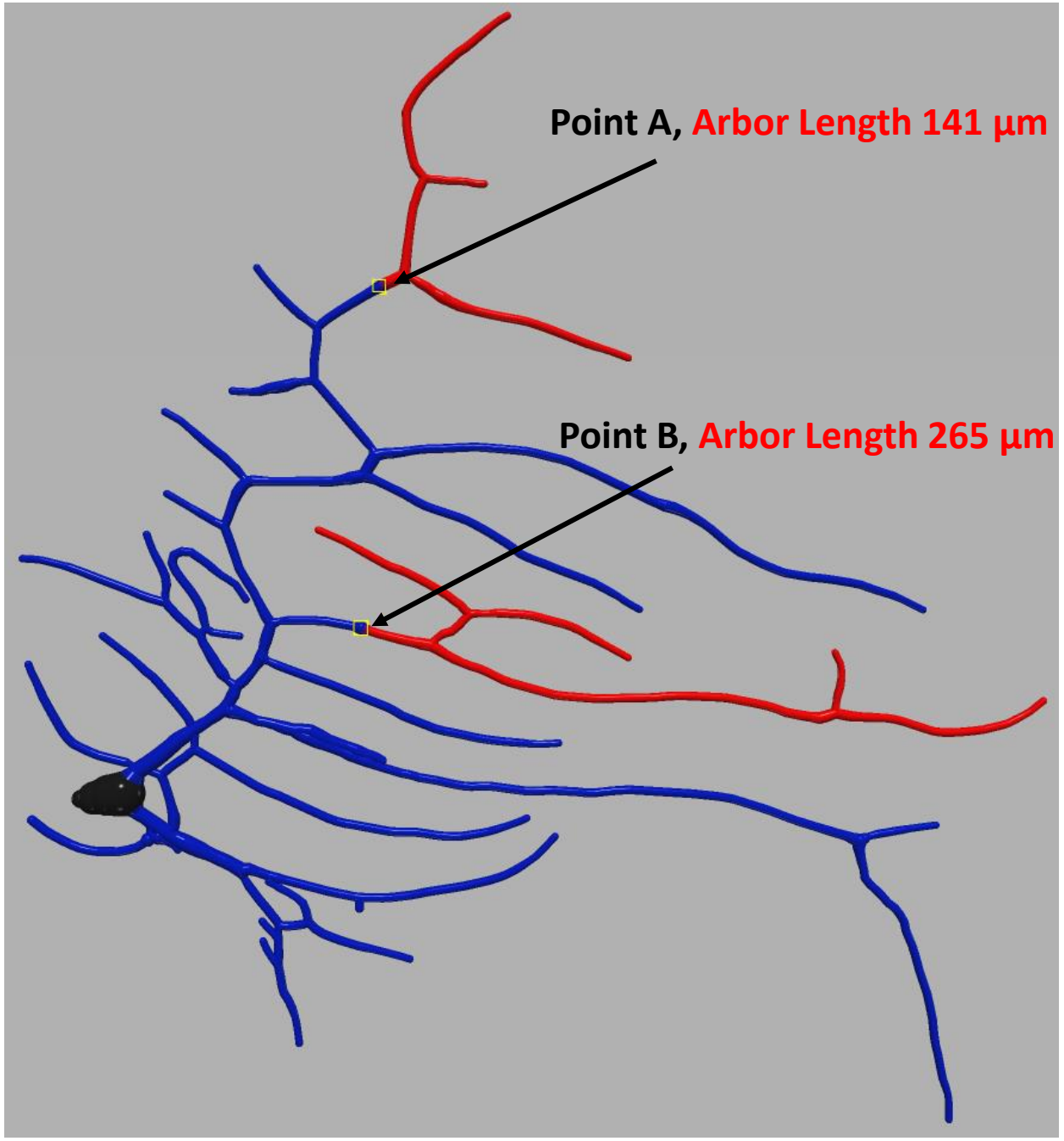
I	T	X	Y	Z	R	P	Ratio_MT	Mean_MT	SD_MT	Ratio_F-act	Mean_F-act	SD_F-act
370	3	280.32	32.32	2.46	1.02	4	0.73	103.84	90.69	0.85	109.67	92.97
371	3	278.80	34.36	2.14	0.75	370	0.68	95.26	72.24	0.66	58.43	38.92
372	3	276.65	36.32	2.25	0.80	371	0.70	84.08	64.25	0.62	38.17	21.32
373	3	274.70	38.55	2.35	1.02	372	0.57	80.04	65.61	0.64	76.40	66.61
374	3	272.60	40.88	2.45	1.05	373	0.55	71.12	61.50	0.68	63.20	50.84
375	3	270.97	43.13	2.50	0.86	374	0.62	65.78	59.99	0.60	45.58	28.41
376	3	271.33	45.83	2.79	1.09	375	0.80	78.51	70.50	0.70	69.20	65.09
377	3	272.49	44.68	2.89	0.46	376	0.67	86.07	76.56	0.72	79.20	70.52
378	3	272.76	43.03	2.90	0.46	377	0.67	50.50	27.82	0.56	36.40	19.23
379	3	273.45	41.89	2.75	0.46	378	0.42	56.20	59.63	0.75	47.33	28.25
380	3	270.00	48.71	3.25	0.75	376	0.67	73.76	73.04	0.61	76.89	74.41
381	3	268.17	51.56	3.18	0.75	380	0.68	34.16	14.66	0.36	26.90	7.48
382	3	266.77	53.79	3.40	0.75	381	0.68	73.76	61.79	0.78	62.17	45.82
383	3	264.69	55.57	3.19	0.75	382	0.67	68.65	50.67	0.74	65.82	45.24
384	3	266.47	56.48	3.32	0.74	383	0.41	41.73	11.27	0.48	41.15	18.94
385	3	267.76	57.74	3.37	0.62	384	0.00	0.00	0.00	0.55	51.67	43.20
386	3	262.10	58.11	3.09	0.75	383	0.54	50.58	29.27	0.60	48.76	26.44
387	3	259.89	60.45	2.80	0.79	386	0.67	73.79	58.80	0.74	74.58	62.04
388	3	257.72	62.46	2.45	1.09	387	0.67	83.65	66.88	0.81	86.44	65.48

Nanda et al. 2018, Sci. Data

Vaa3D Multi_channel_SWC plugin Demo

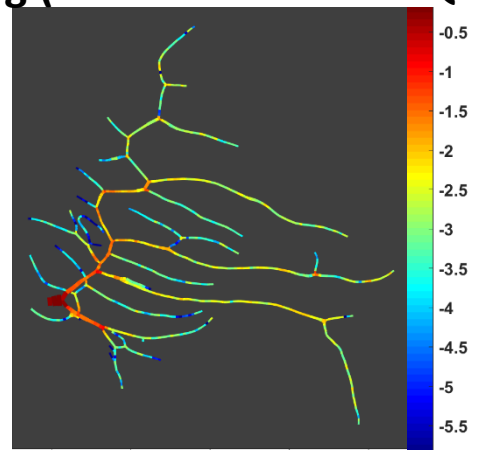

Microtubule
UASmCherry::Jupiter
F-act
UAS-GMA::GFP
Class I
Class IV
C IV
Form3OE

Arbor Length: Total Length (µm), Downstream of a point

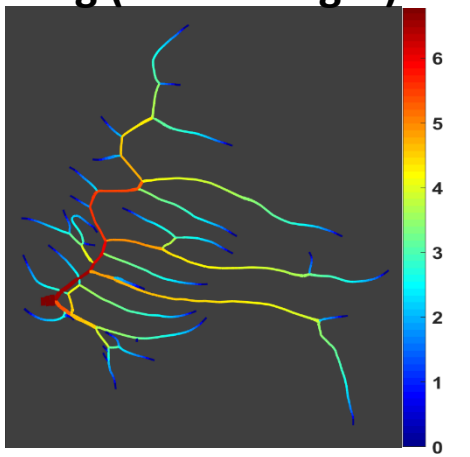


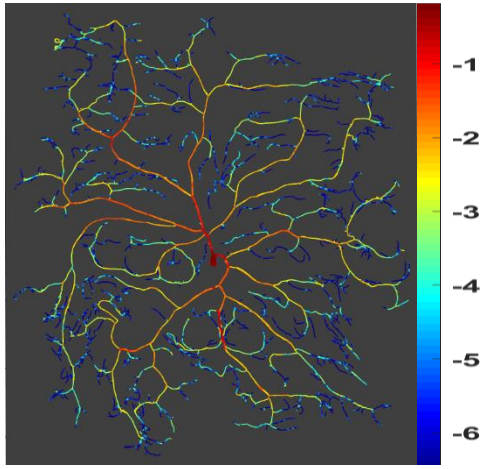
Log (Local Microtubule Qt.)

Log (Arbor Length)

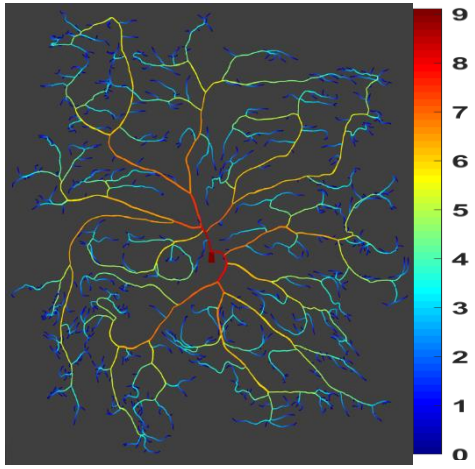


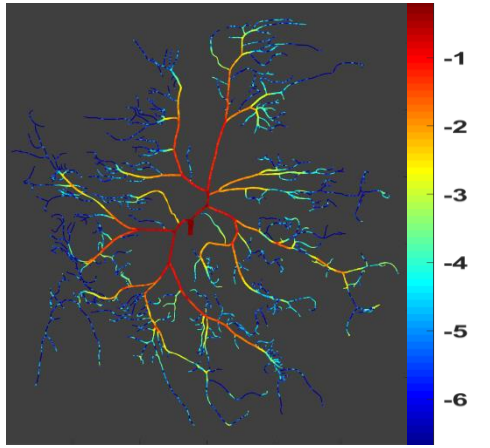
CI



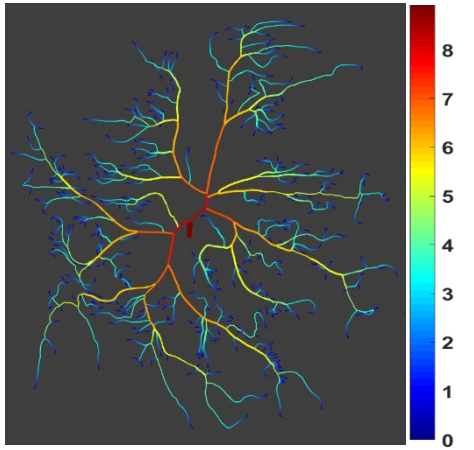


CIV WT





CIV Form3OE



Microtubule is the strongest discriminant of arbor length

Pearson correlation coefficients of arbor length against morphological and cytoskeletal parameters at the resolution of single (2 µm long) compartments. Microtubule quantity is the best predictor of arbor length for all the cell types.

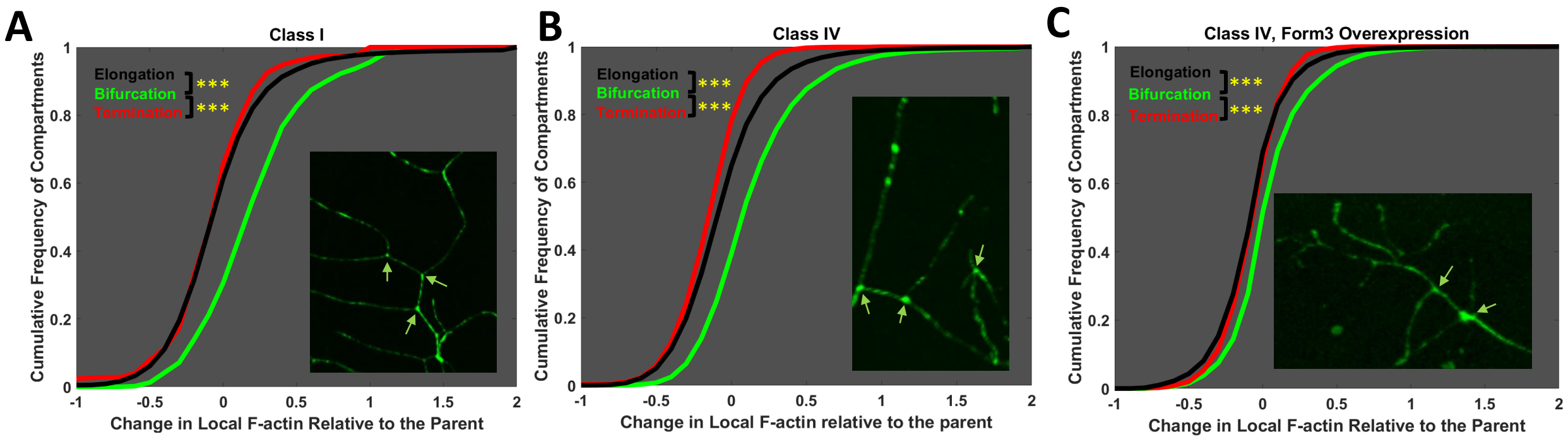
Cell Type	MT quantity	F-act quantity	MT + F-act quantity	Path distance from soma	Branch order	Diameter
Class I	**0.67**	0.55	0.62	-0.47	-0.33	0.64
Class IV	**0.79**	0.43	0.63	-0.45	-0.42	0.49
Class IV Form3OE	**0.88**	0.76	0.82	-0.47	-0.39	0.61

Nanda et al. 2020, iScience

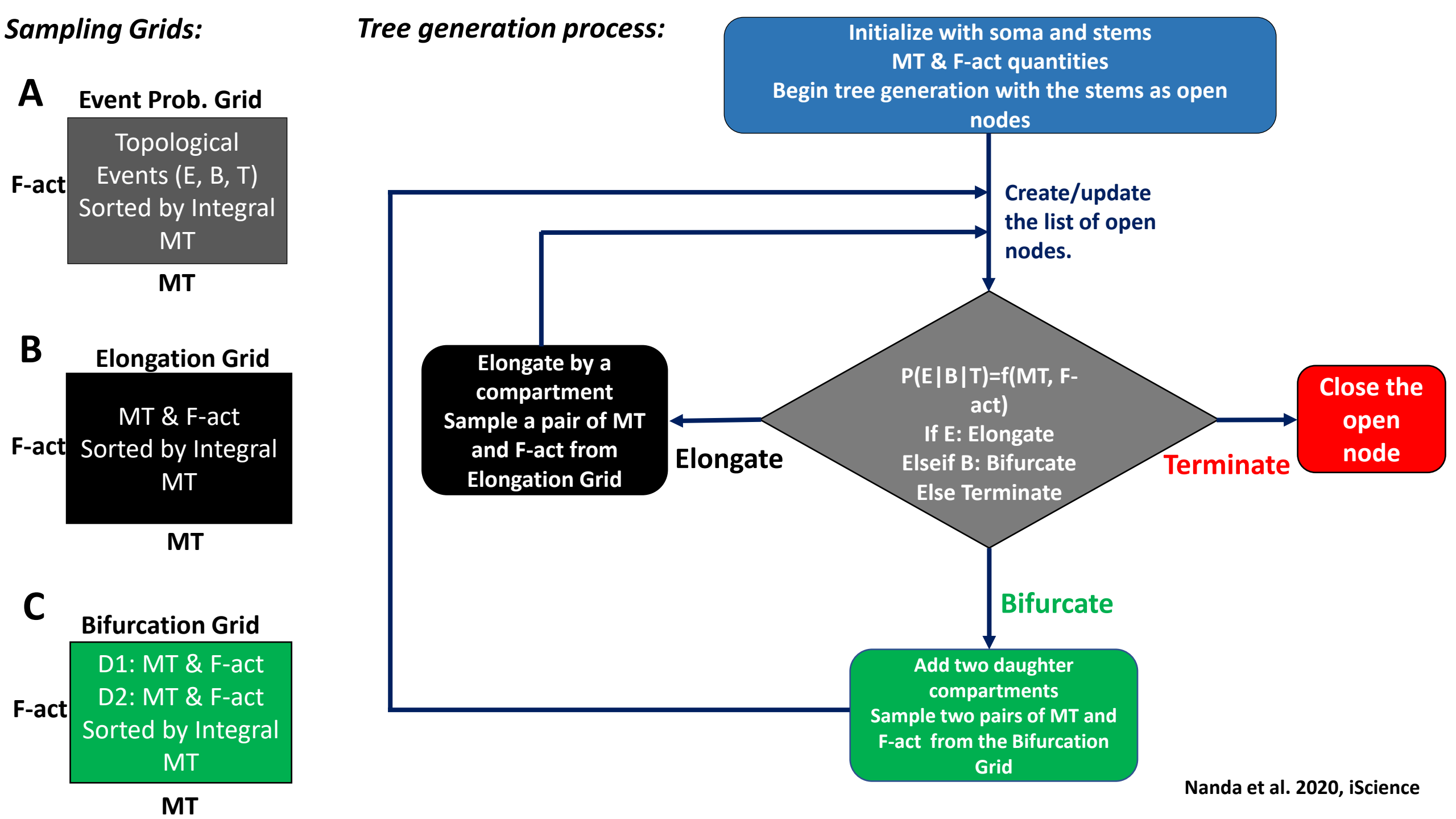
Bifurcation points are richer in F-actin

Cumulative frequency of bifurcating (green), elongating (black) and terminating (red) compartments as a function of change in local F-actin concentration relative to the parent compartment.

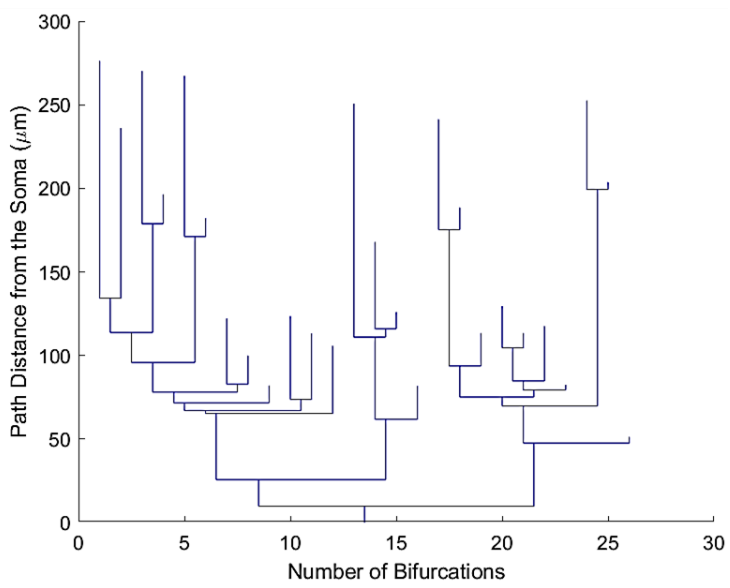
The bifurcating compartments are enriched in F-actin

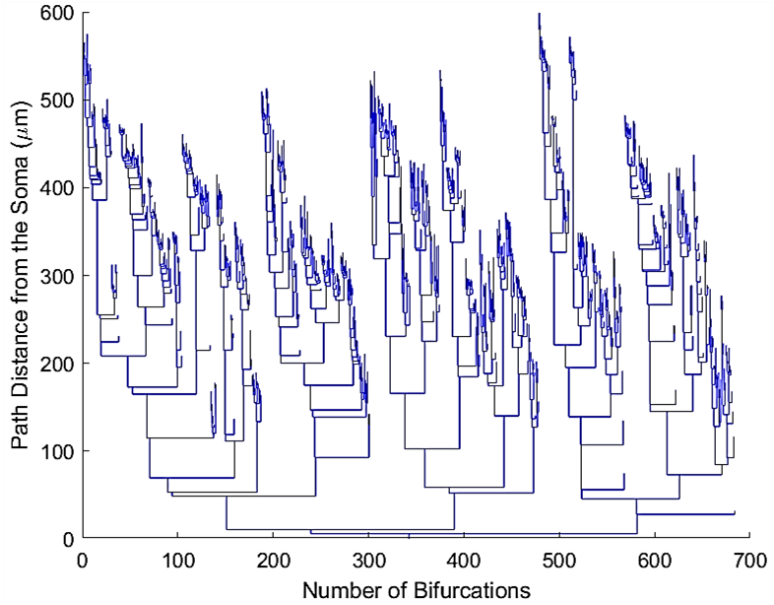


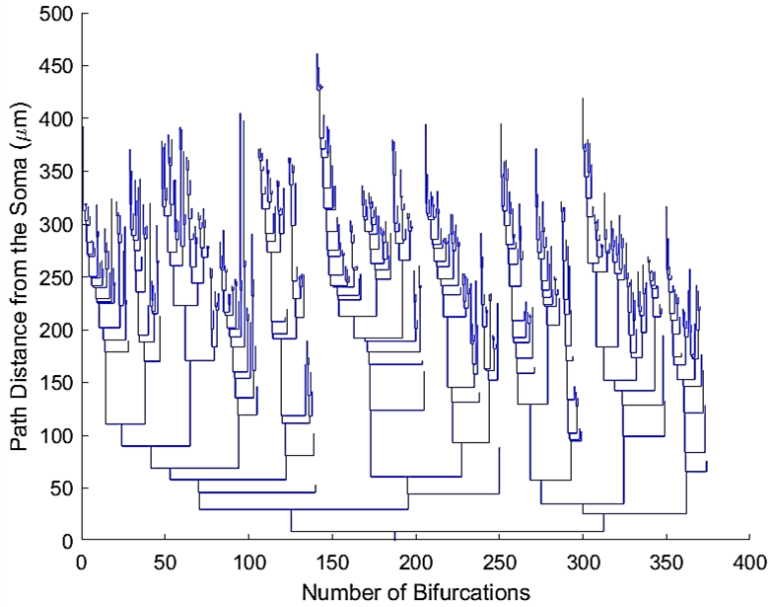
Nanda et al. 2020, iScience


Sampling Grids:
A
Event Prob. Grid
Topological Events (E, B, T) Sorted by Integral MT
F-act
MT
B
Elongation Grid
MT & F-act Sorted by Integral MT
F-act
MT
C
Bifurcation Grid
D1: MT & F-act
D2: MT & F-act
Sorted by Integral MT
F-act
MT
Tree generation process:
Initialize with soma and stems
MT & F-act quantities
Begin tree generation with the stems as open nodes
Create/update the list of open nodes.
P(E|B|T)=f(MT, F-act)
If E: Elongate
Elseif B: Bifurcate
Else Terminate
Elongate
Elongate by a compartment
Sample a pair of MT and F-act from Elongation Grid
Terminate
Close the open node
Bifurcate
Add two daughter compartments
Sample two pairs of MT and F-act from the Bifurcation Grid
Nanda et al. 2020, iScience

Model prediction: Dendrograms of real (top, blue) and simulated (bottom, red) Class I, Class IV and mutant Class IV Form3OE neurons.



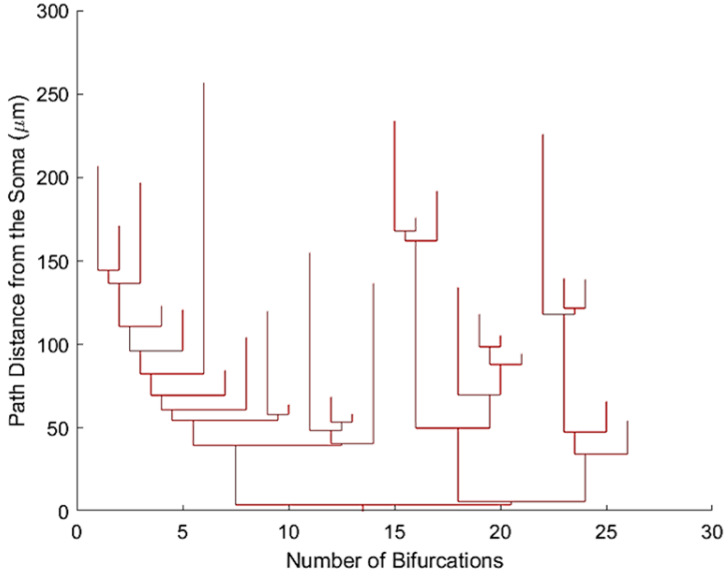


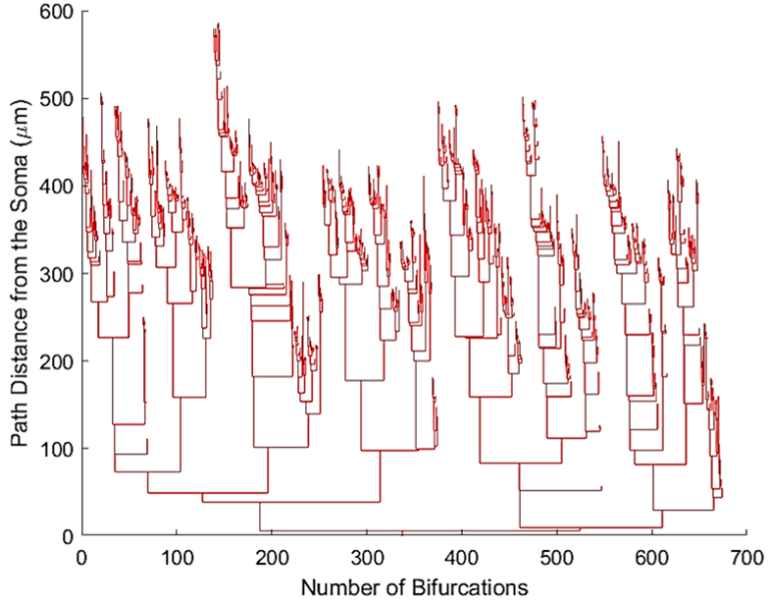


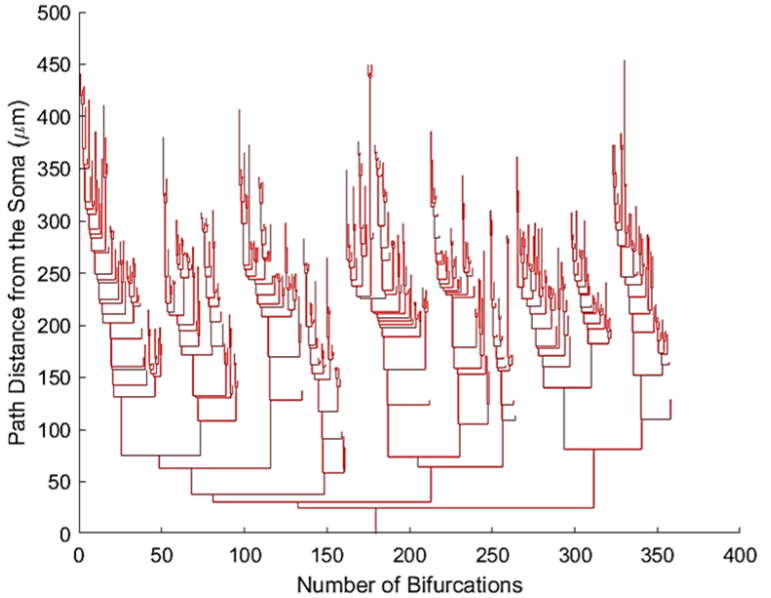
Class I

Class IV WT

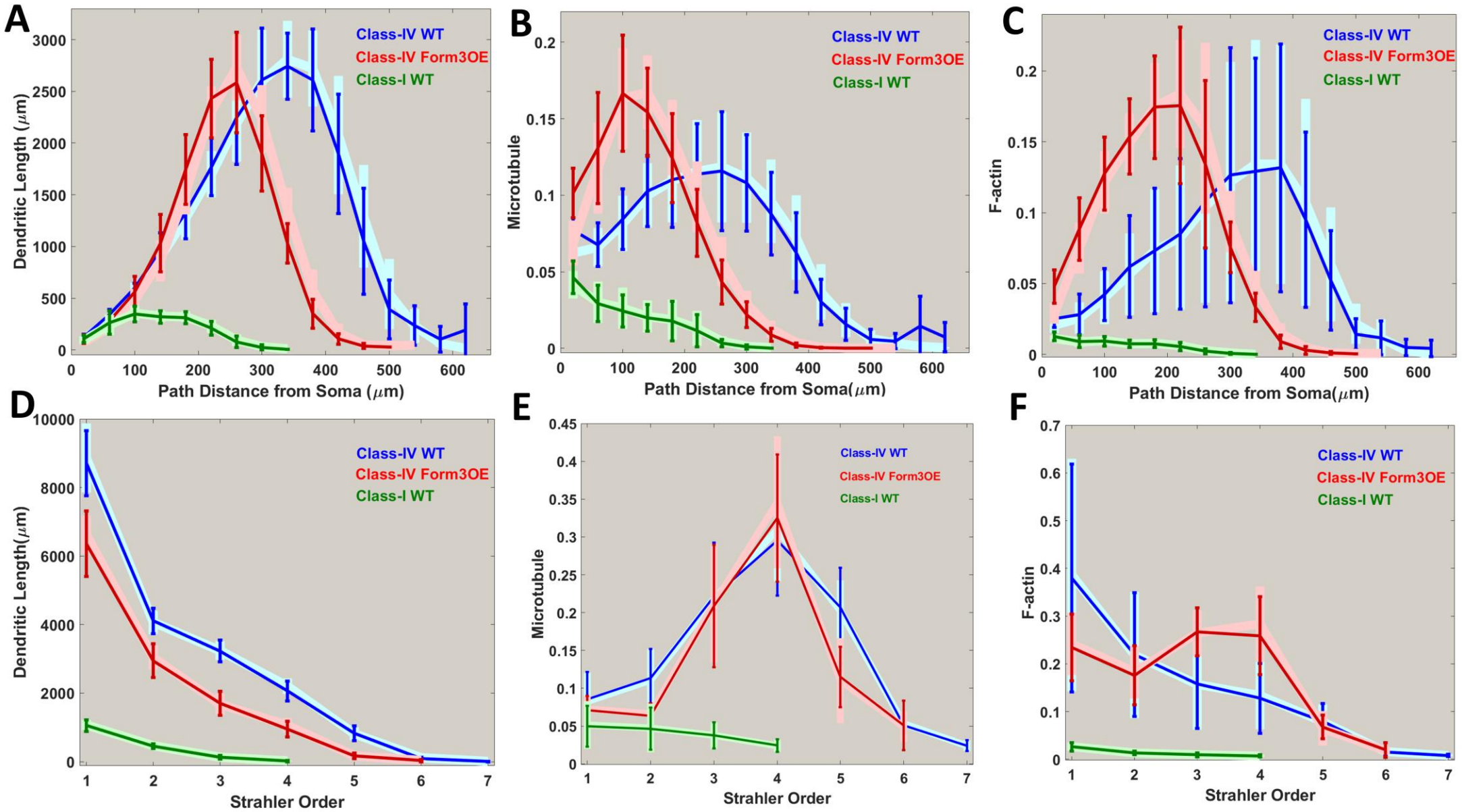
Class IV Form3OE







Model prediction: Emergent distributions of Dendritic length, Microtubule and F-actin by path distance and Strahler order, Observed distributions are overlaid in the background (in lighter shades of blue, red and green).



Nanda et al. 2020, iScience

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