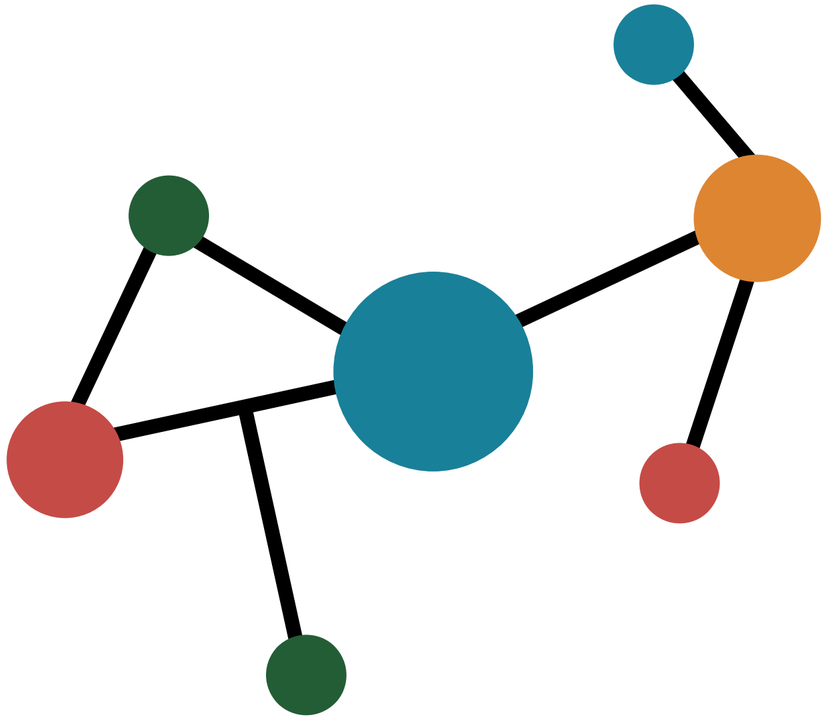
Lelia Erscoi
Data Science 2023

Brain Area Distances

Graph-Physical



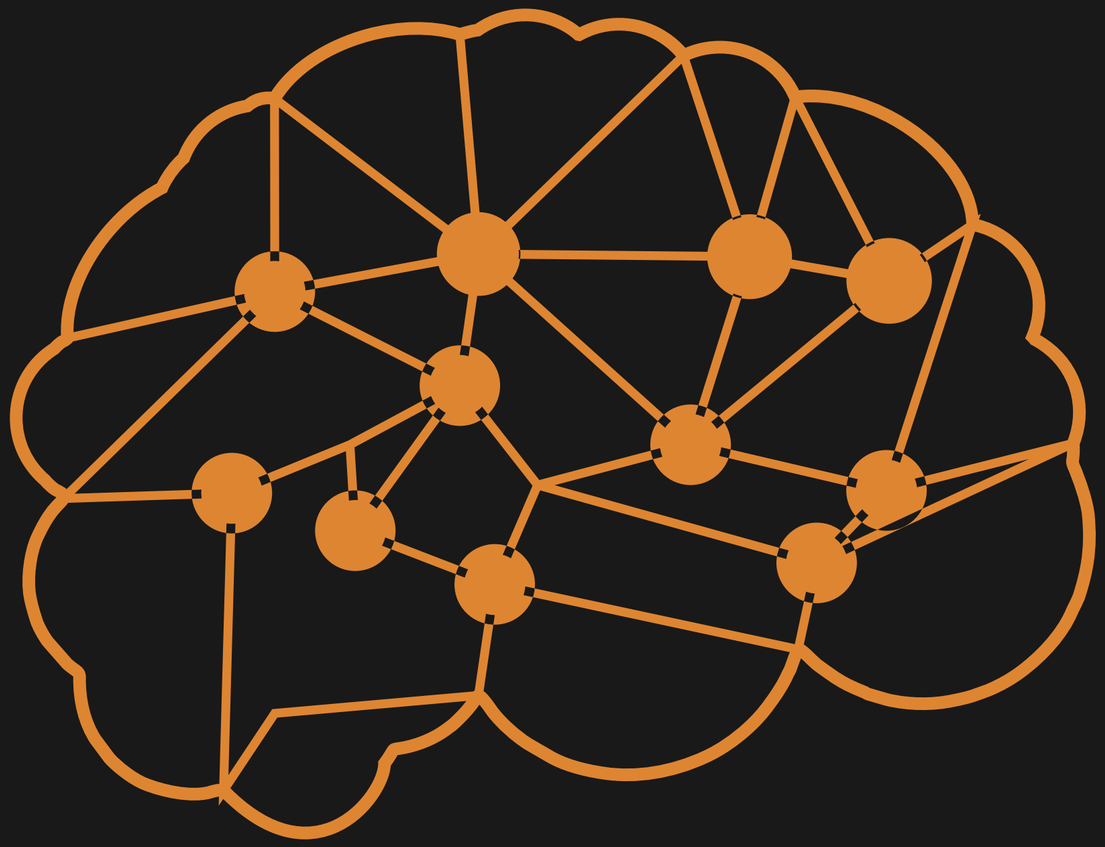
Research Question

Is it possible to extract patterns of between-brain area physical distance by constructing a connectome-based graph?

Why?

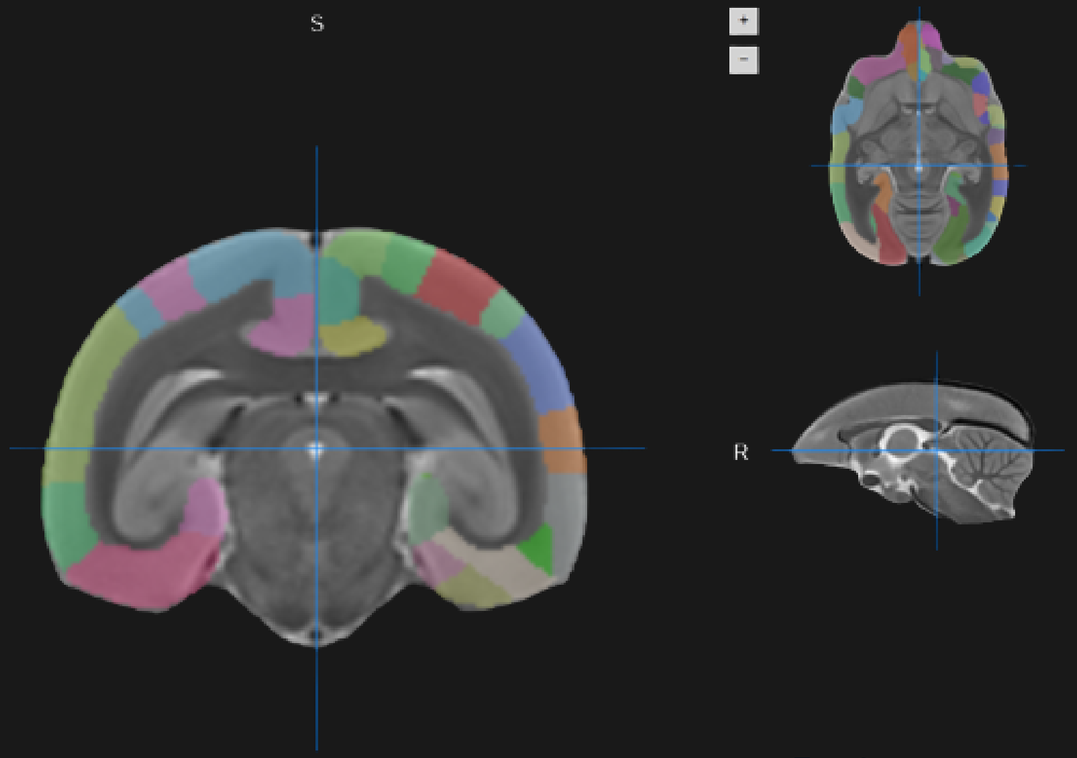
Examine the relationship between functionality and topology.

Easily build highly-relevant models.

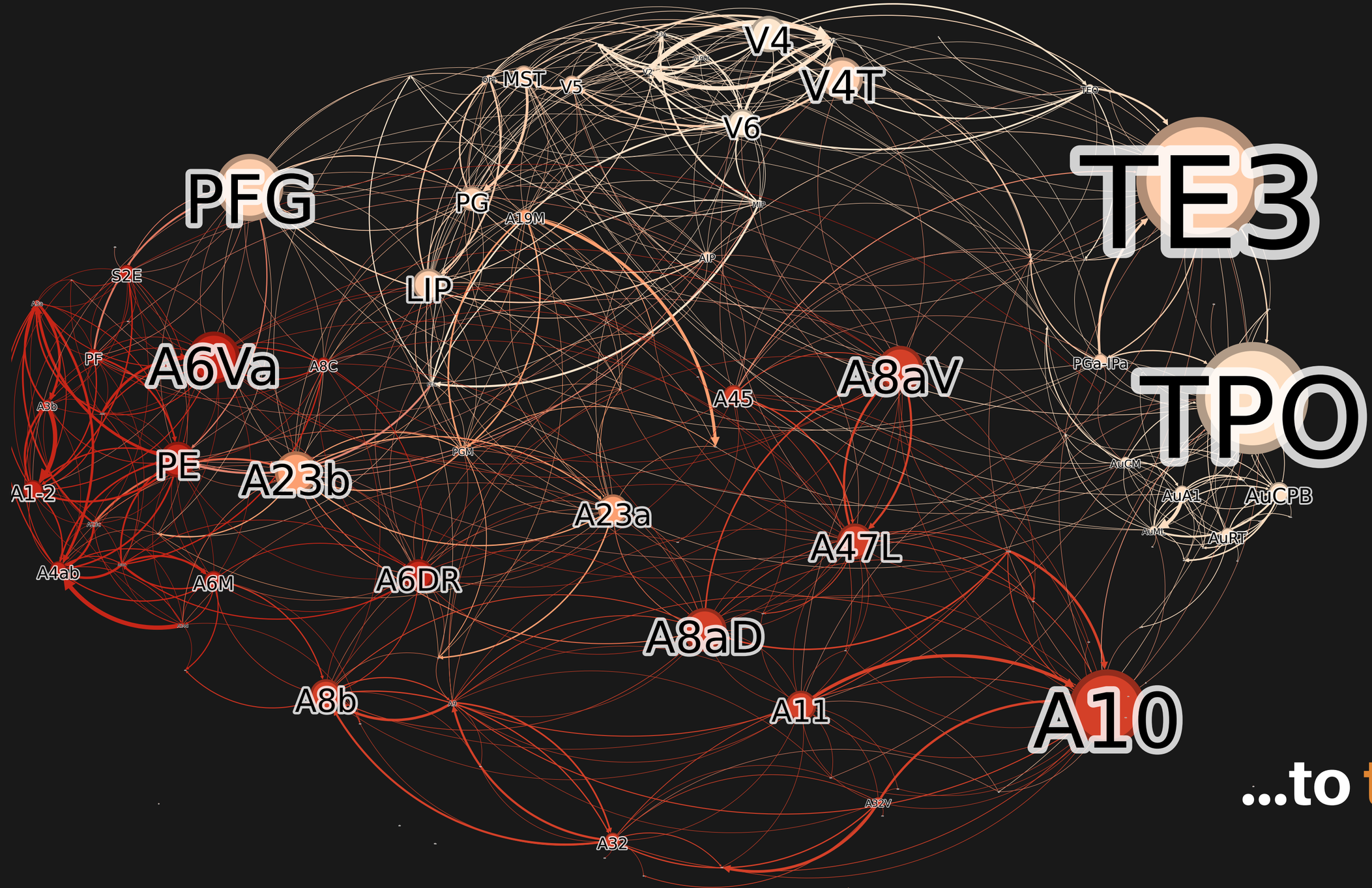


How?

From this...



...to this...


V4
V4T
V6
MST
V5
PFG
PG
A19M
LIP
S2E
A6Va
PF
A8C
A3b
PE
A23b
A1-2
A4ab
A6M
A6DR
A45
A8aV
A23a
A47L
A8aD
A8b
A11
A10
A32V
A32
TE3
TPO
PGa-IPa
AuCM
AuA1
AuCPB
AuML
AuRT

...to this!

2 Types of Data

Brain Connectome

Injection data, measured in fraction of total labeled neurons

Brain Area Distances

Physical distance , measured in micrometers

MarmosetBrain.org

2 Types of Data

Brain Connectome

Projections of different strengths, measured in fraction of total neurons

Brain Area Distances

Physical distance , measured in micrometers

Connectome Graph

Network Graph Construction

Connectome
Graph

Nodes
shortest
path

×

Edge
Weights

=

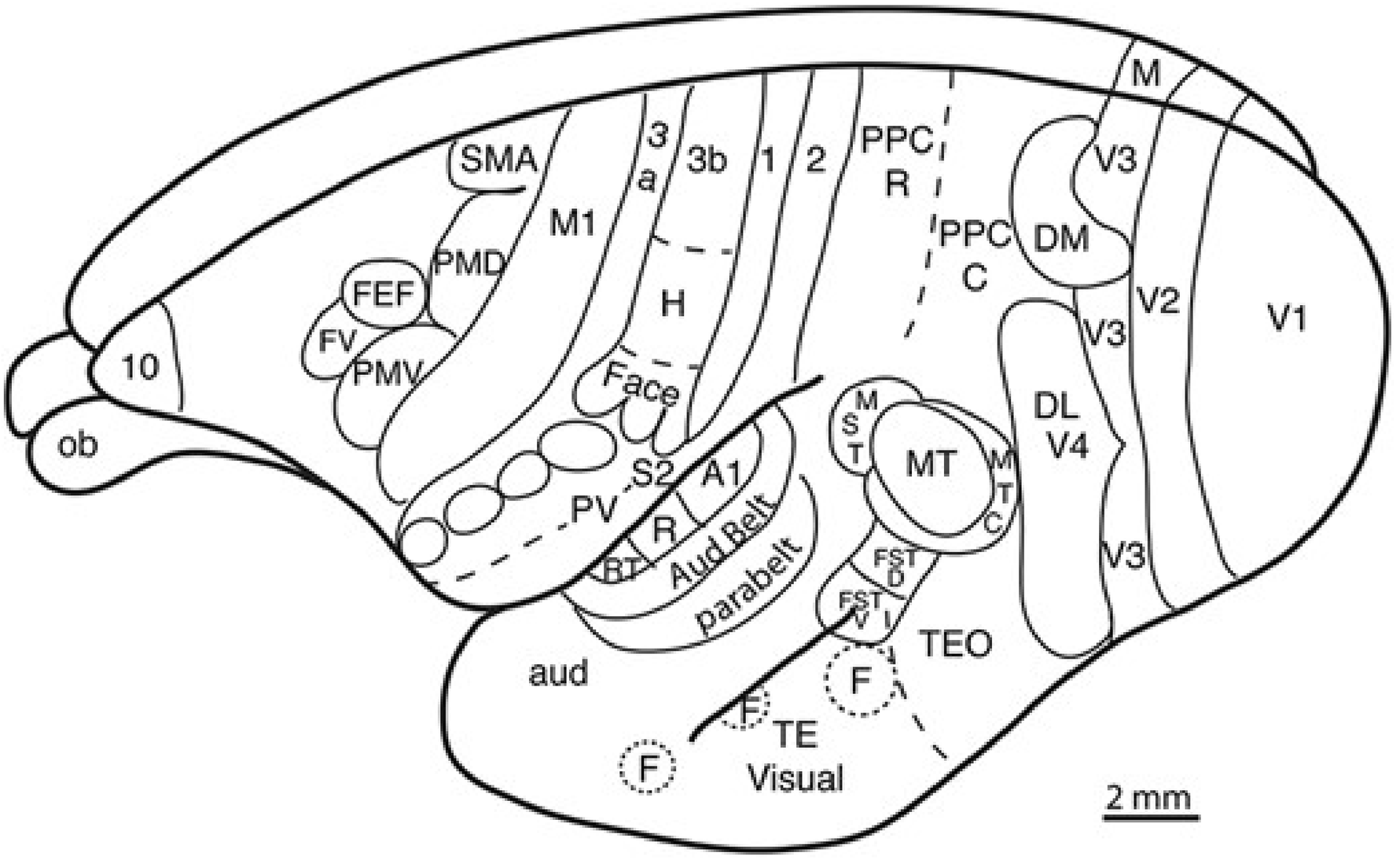
Graph
Distances

Hypothesis

Brain Area Distances

are strongly correlated to

Connectome Graph Distances


SMA
PMD
FEF
FV
PMV
10
ob
M1
3
a
3b
1
2
H
Face
PPC
R
PPC
C
M
V3
DM
V2
V1
V3
DL
V4
V3
S2
A1
PV
R
RT
Aud Belt
parabelt
M
S
T
MT
M
T
C
FST
D
FST
V
I
TEO
aud
F
F
F
TE
Visual
2 mm

Brain measured distances

Mean: 12.43
Std: 5.3

Source	Target	Brain Distance
AuR	AURM	0.37
S2E	S2I	0.96
A24c	A24b	1.04
A36	A35	1.07
AuRTL	AuRTM	1.08

Closest brain areas in space

(not normalized)

Source	Target	Brain Distance
V1	APir	28.43
V1	A10	26.88
Ent	V1	26.58
V3	A10	26.35
A13b	V1	26.13

Furthest brain areas in space

(not normalized)

Density: 0.4

Transitivity: 0.59

Small world:

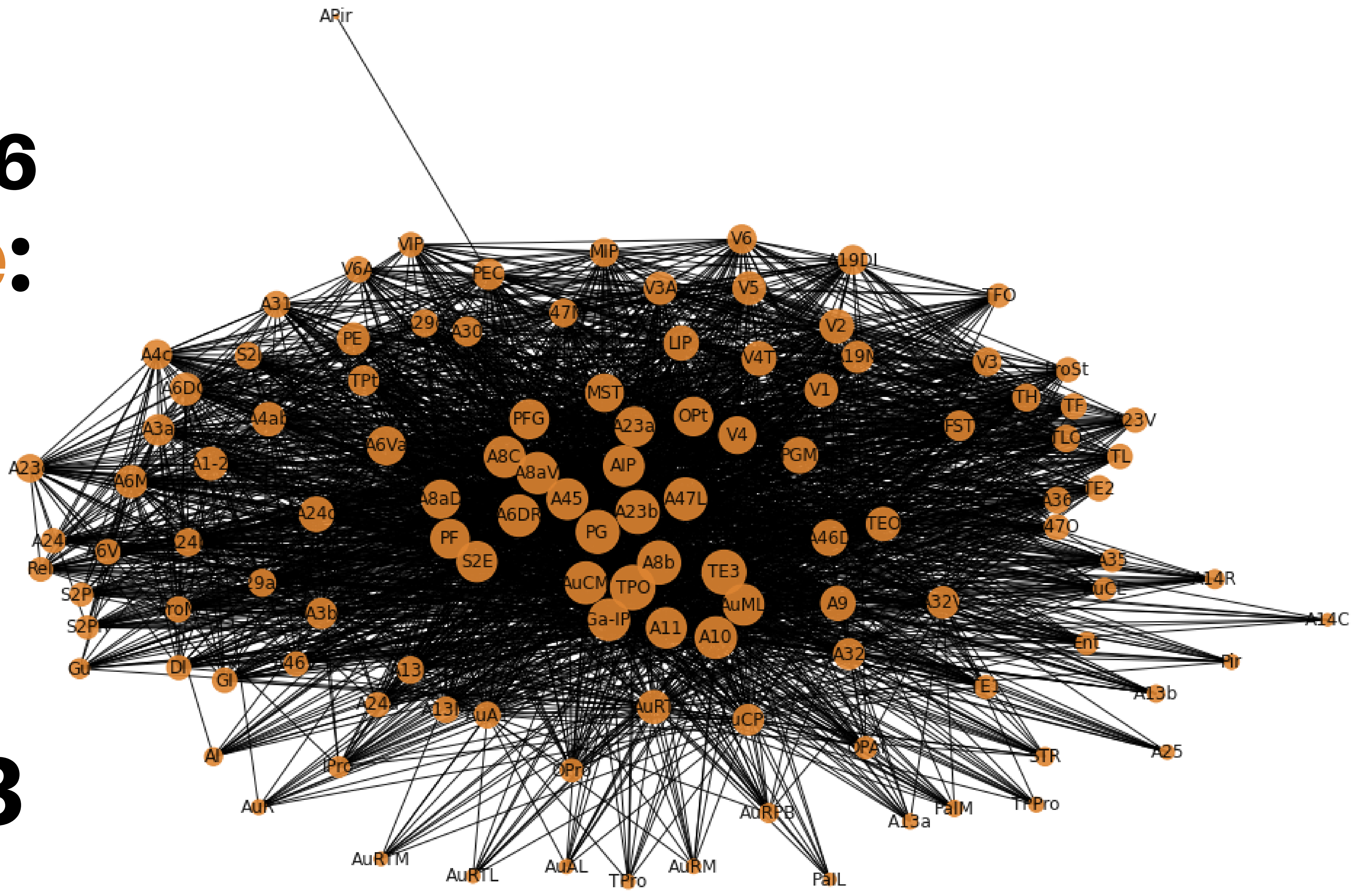
- Avg clust = 0.73
- Avg shortest path = 1.6

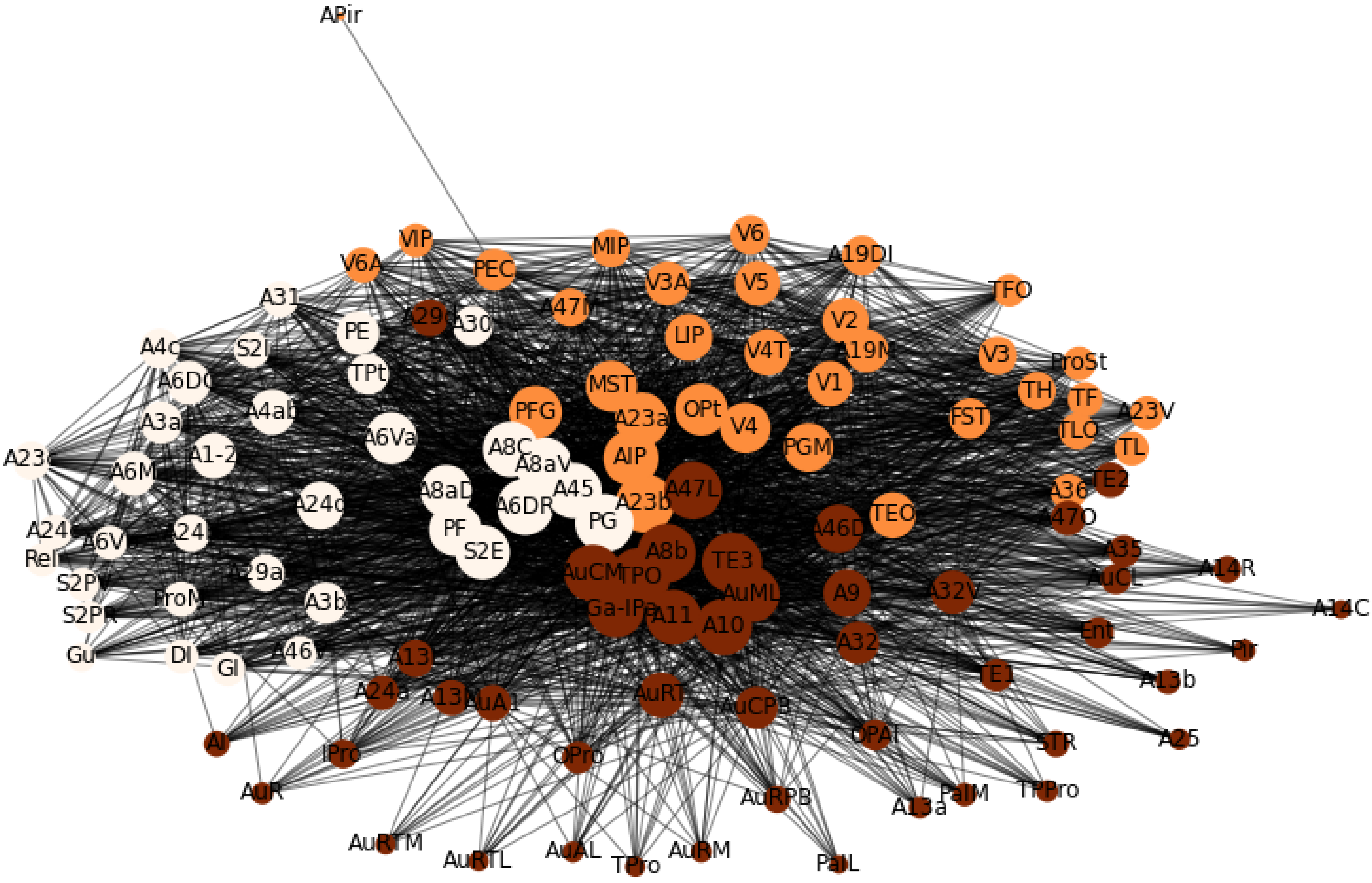
Top nodes by degree:

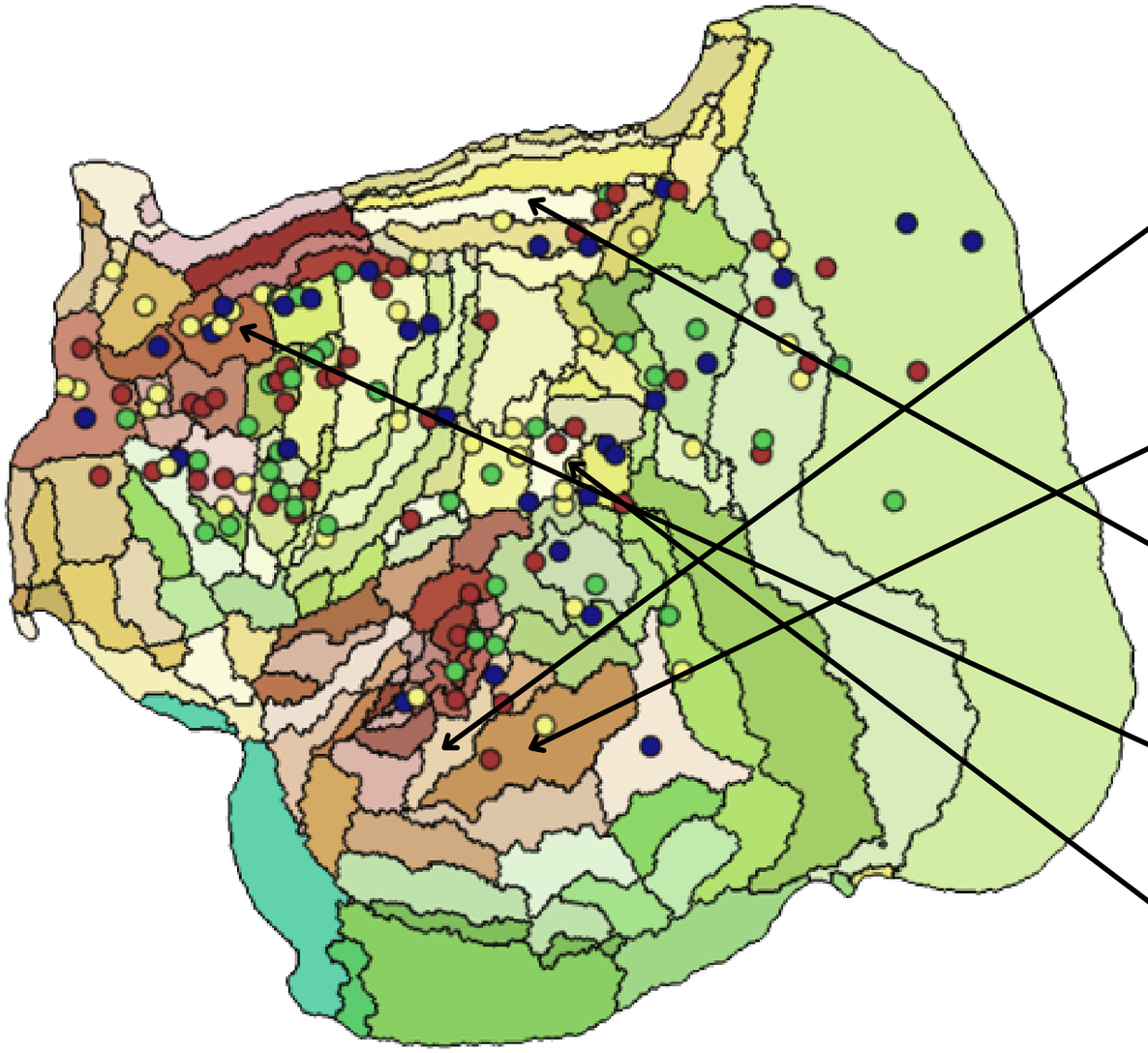
- TPO: 106
- TE3: 104
- A23b: 100
- A8b: 100
- PG: 90

Nr. of Communities: 3

- Comm 1: 36 areas
- Comm 2: 35 areas
- Comm 3: 45 areas




APir
VIP
V6A
PEC
MIP
V6
V5
V3A
A19DI
TFO
A31
A30
LIP
V2
V4T
V3
ProSt
A4c
PE
TPt
MST
OPt
V1
TH
TF
A23V
PFG
A4ab
A23a
V4
FST
TLO
A6Va
A8C
AIP
PGM
TL
A1-2
A6M
A8aV
A47L
A8aD
A45
A23b
A24d
A6DR
TEO
PG
A46D
A6V
PF
S2E
A8b
TE3
A35
A14R
TPO
AuCL
A29a
AuML
A32V
A9
A14C
Ga-IPa
A11
A10
A3b
Ent
Gu
DI
GI
A32
TE1
A13b
A24a
AuRT
AuCPB
A25
AI
OPro
OPAI
STR
AuR
AuRPB
A13a
PaIM
TPPro
AuRTM
AuRTL
AuAL
TPro
AuRM
PaIL



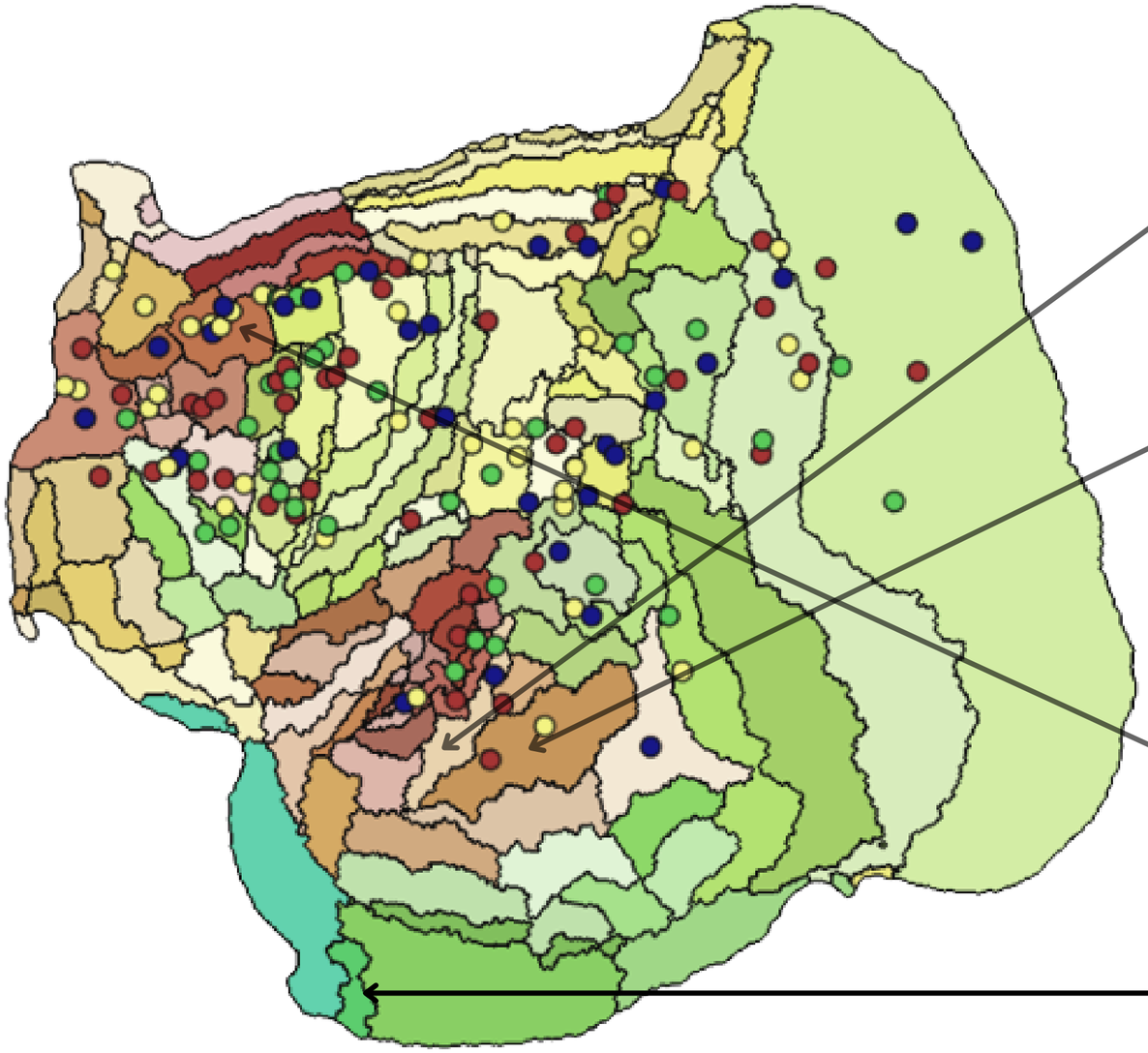
01 **TPO** : temporo-parieto-occipital association area (superior temporal polysensory cortex)
Community 2

02 **TE3** : temporal area TE3 (inferior temporal cortex)
Community 2

03 **A23b** : area 23b of cortex
Community 1

04 **A8b** : area 8b of cortex
Community 2

05 **PG** : parietal area PG
Community 3



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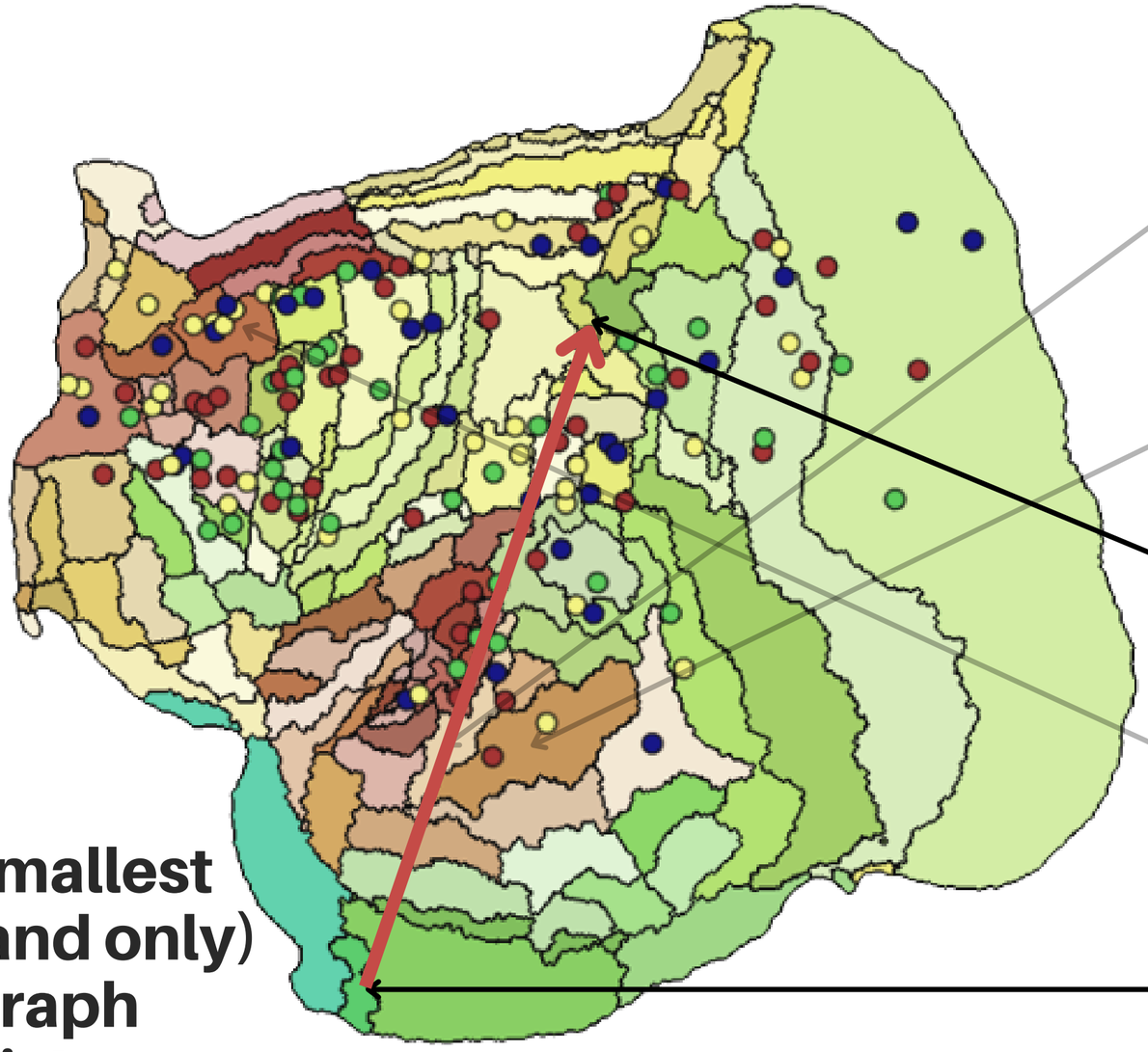
04 **A8b** : area 8b of cortex
Community 2

06 **APir** : Amygdalopiriform transition area
Community 2



Smallest (and only) Graph Distance

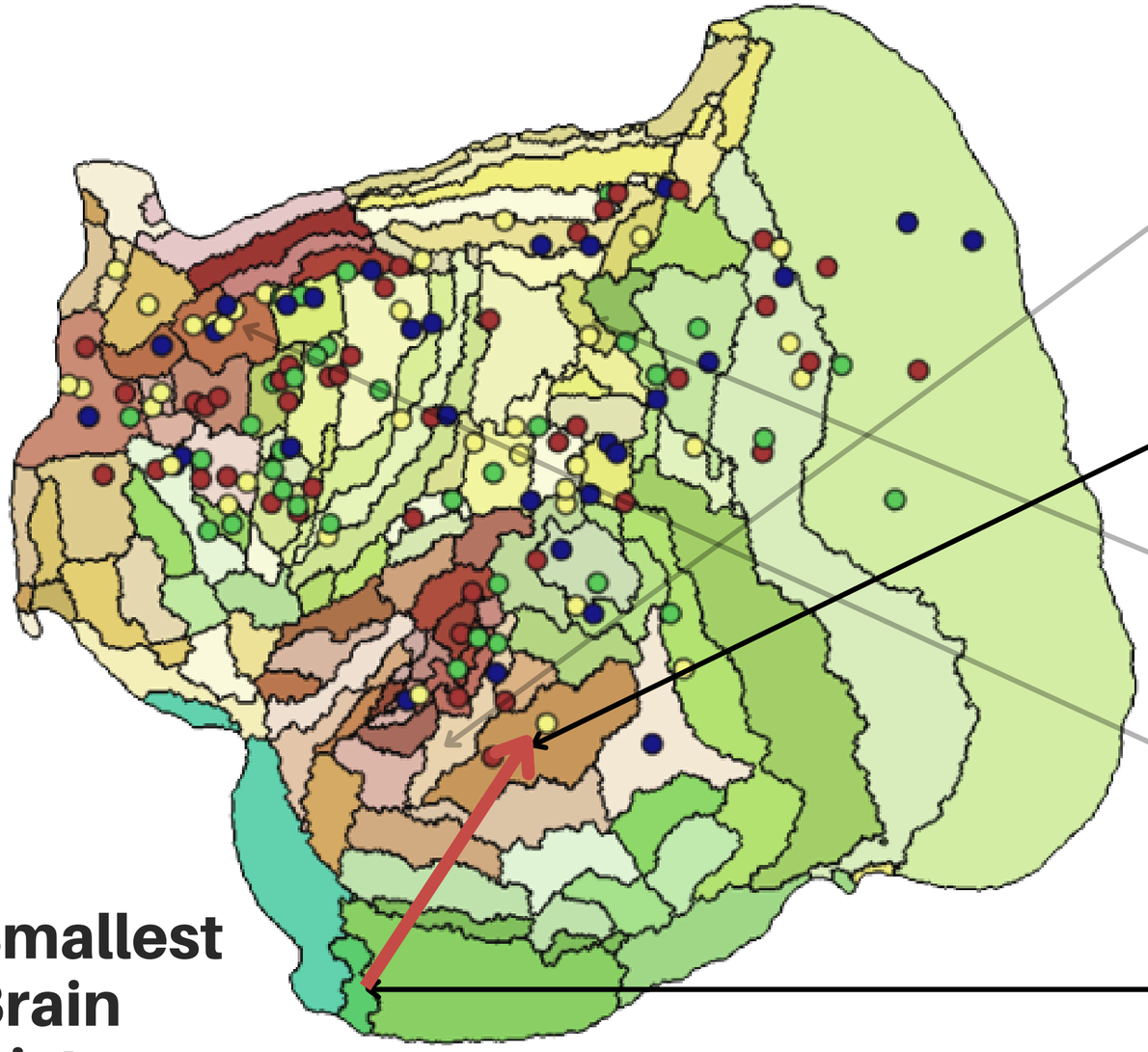
01 **TPO** : temporo-parieto-occipital association area (superior temporal polysensory cortex)
Community 2

02 **TE3** : temporal area TE3 (inferior temporal cortex)
Community 2

07 **PEC** : Parietal area PE, caudal part
Community 2

04 **A8b** : area 8b of cortex
Community 2

06 **APir** : Amygdalopiriform transition area
Community 2



Smallest Brain Distance

01 **TPO** : temporo-parieto-occipital association area (superior temporal polysensory cortex)
Community 2

02 **TE3** : temporal area TE3 (inferior temporal cortex)
Community 2

07 **PEC** : Parietal area PE, caudal part
Community 2

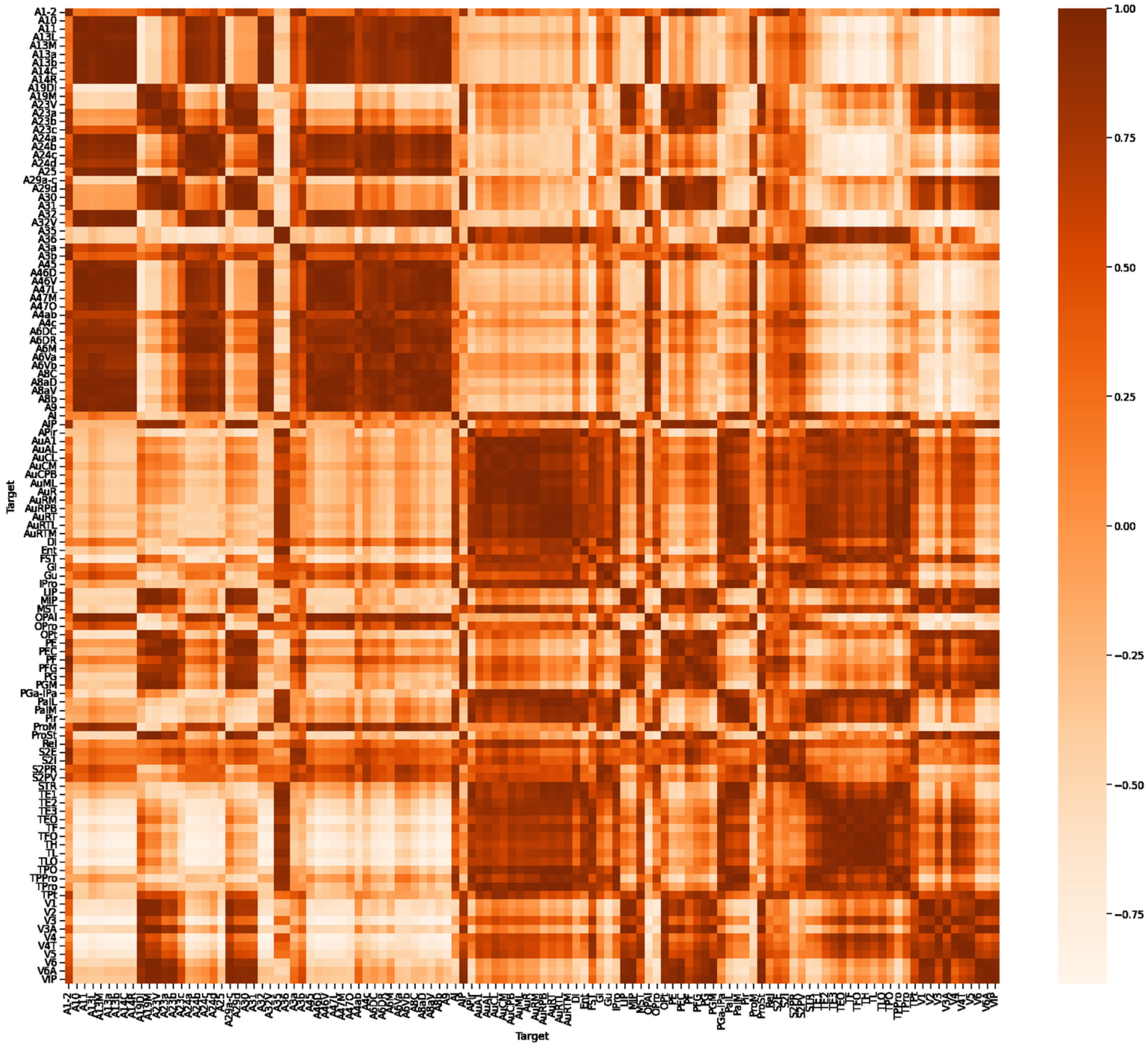
04 **A8b** : area 8b of cortex
Community 2

06 **APir** : Amygdalopiriform transition area
Community 2

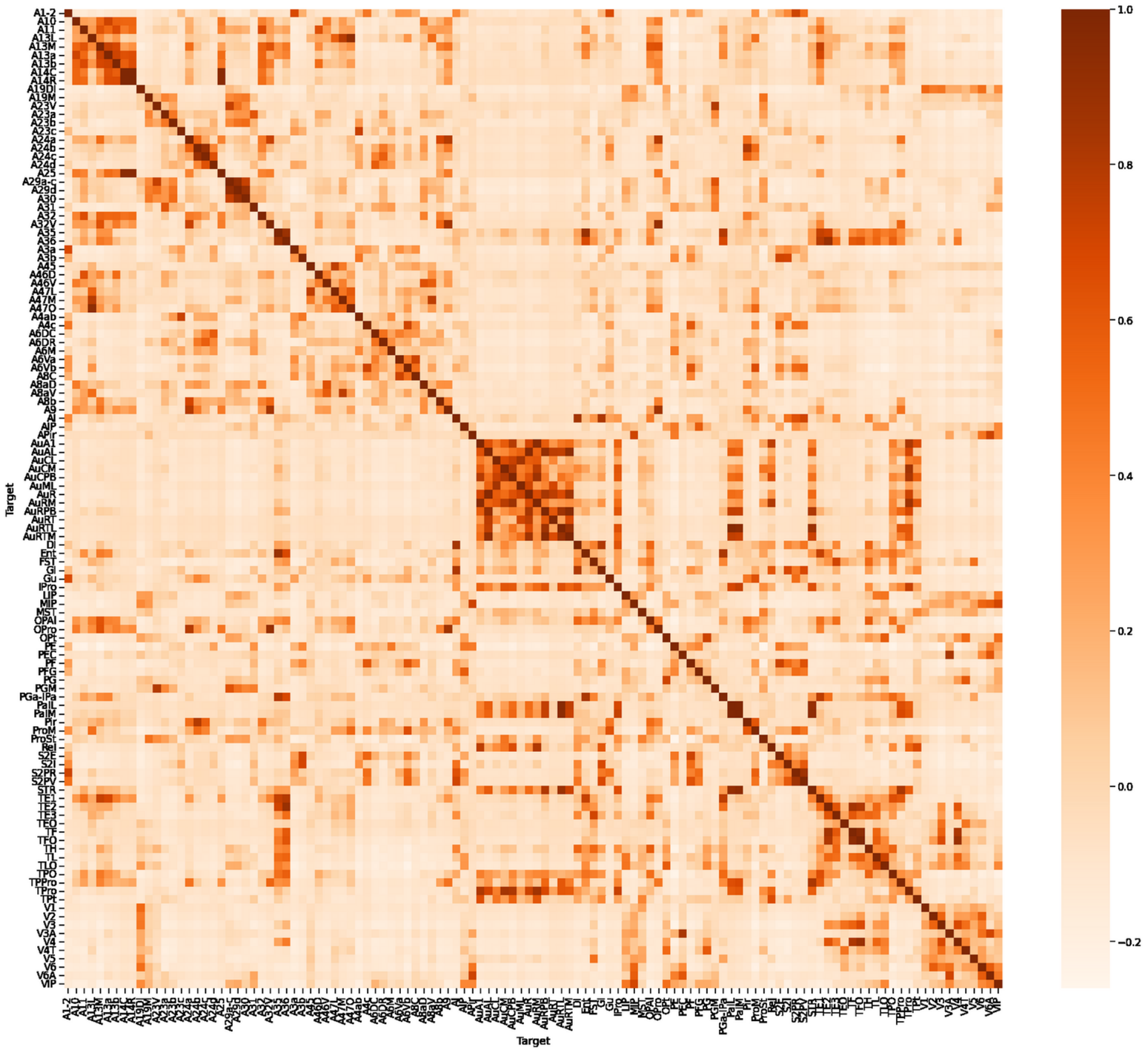
Case study: Amygdalopiriform transition area (APir)

Brain Distance

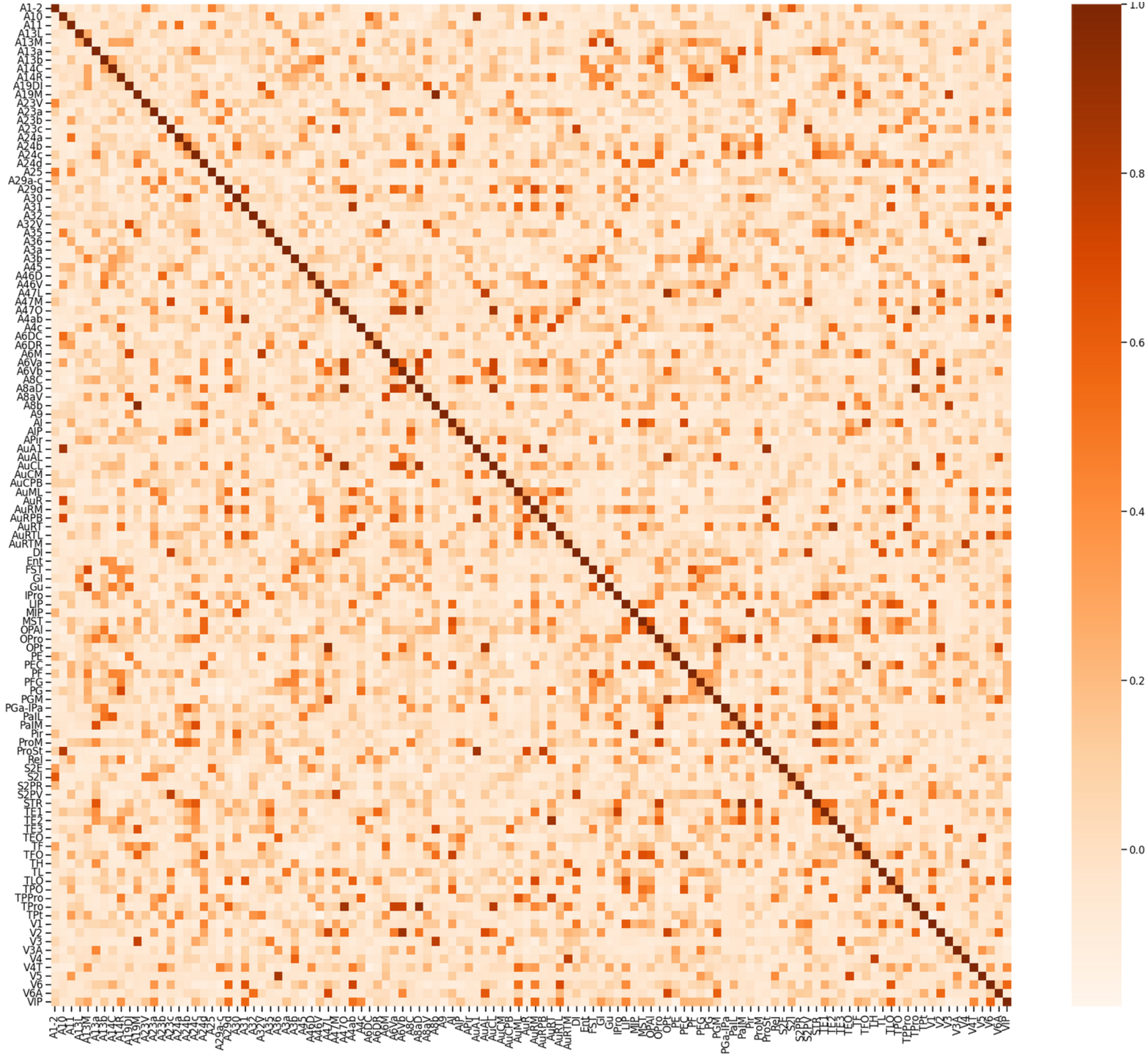
Id	Source	Target	Brain Distance	Graph Distance	Weight	Distance Difference
0	TE3	APir	-0.12	0.31	-	0.22
1	AuCM	APir	0.19	0.28	-	0.55
2	A6Va	APir	0.61	-7.92	-	0.96
3	A3a	APir	0.72	0.36	-	1.08
4	A8C	APir	0.73	-2.56	-	0.93
5	V4	APir	0.75	-3.81	-	1.22
...	...	...	...	...	...	...
25	V3A	APir	1.99	-2.55	-	2.13
26	PEC	APir	2.03	-2.52	0.11	1.81
27	PGM	APir	2.08	-2.66	-	2.37
28	V6	APir	2.38	-2.66	-	2.67
29	V2	APir	2.42	2.47	-	2.77
30	V1	APir	2.98	-6.53	-	3.33



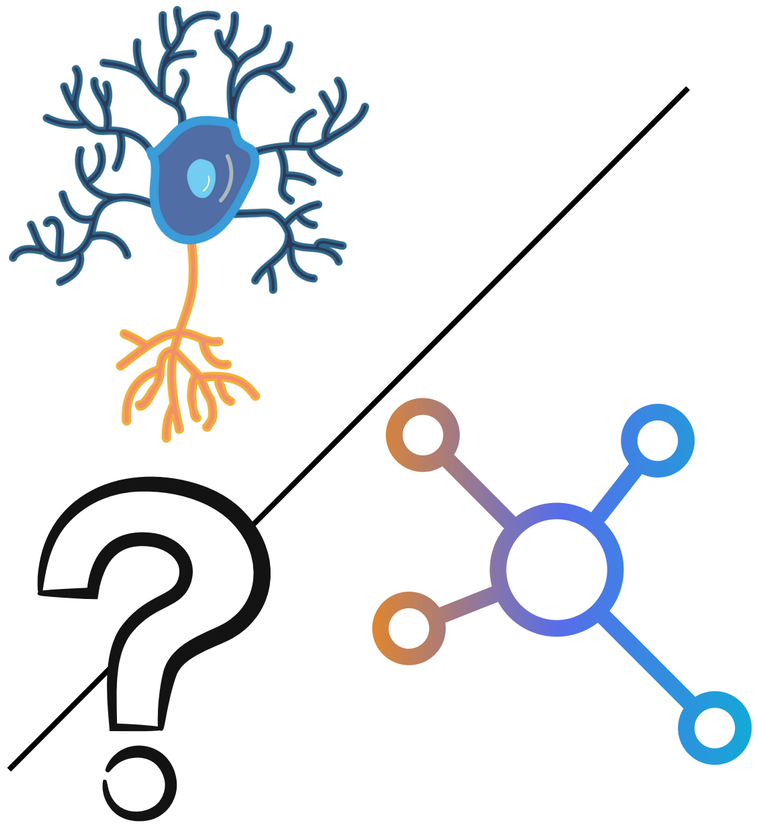
Brain (real distance)

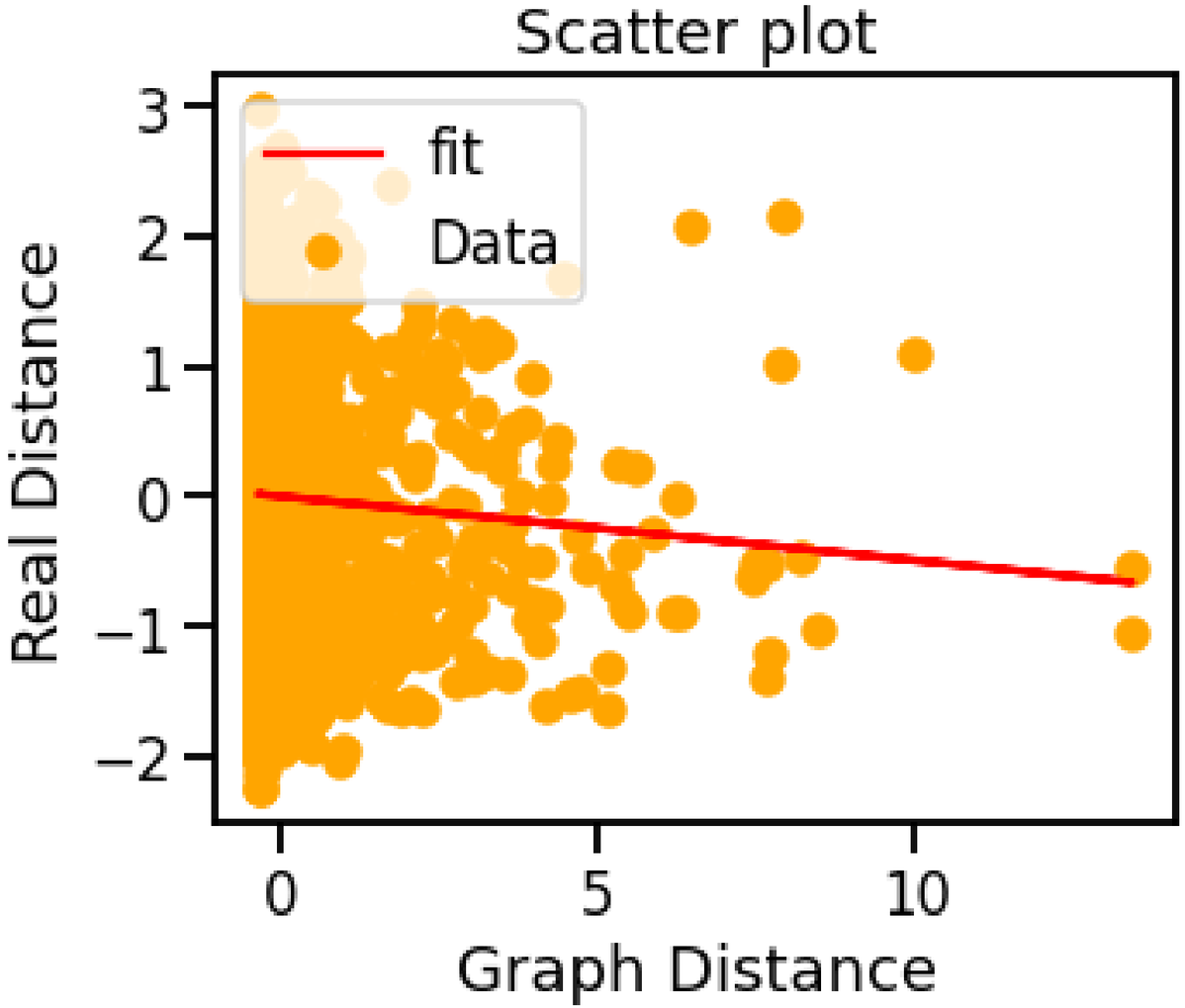


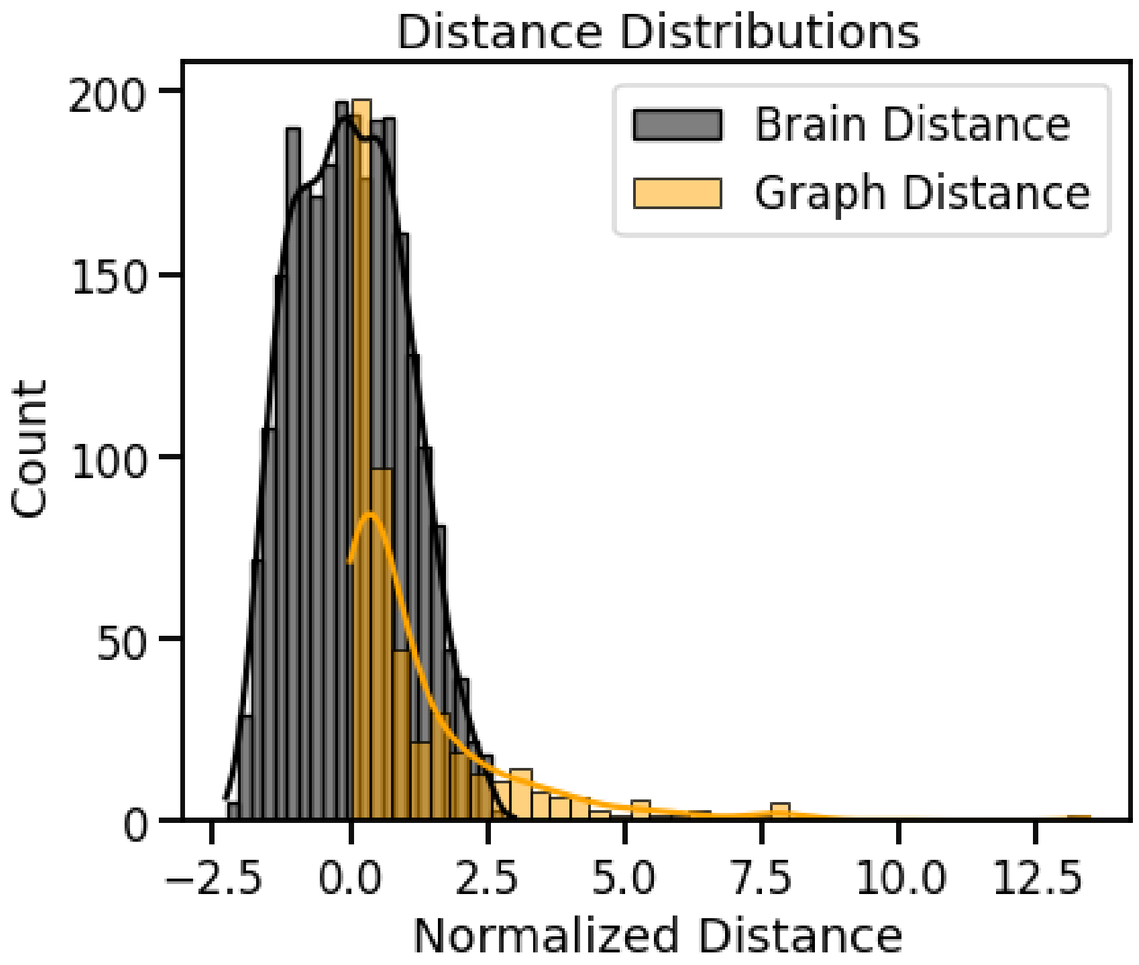
Graph connectome

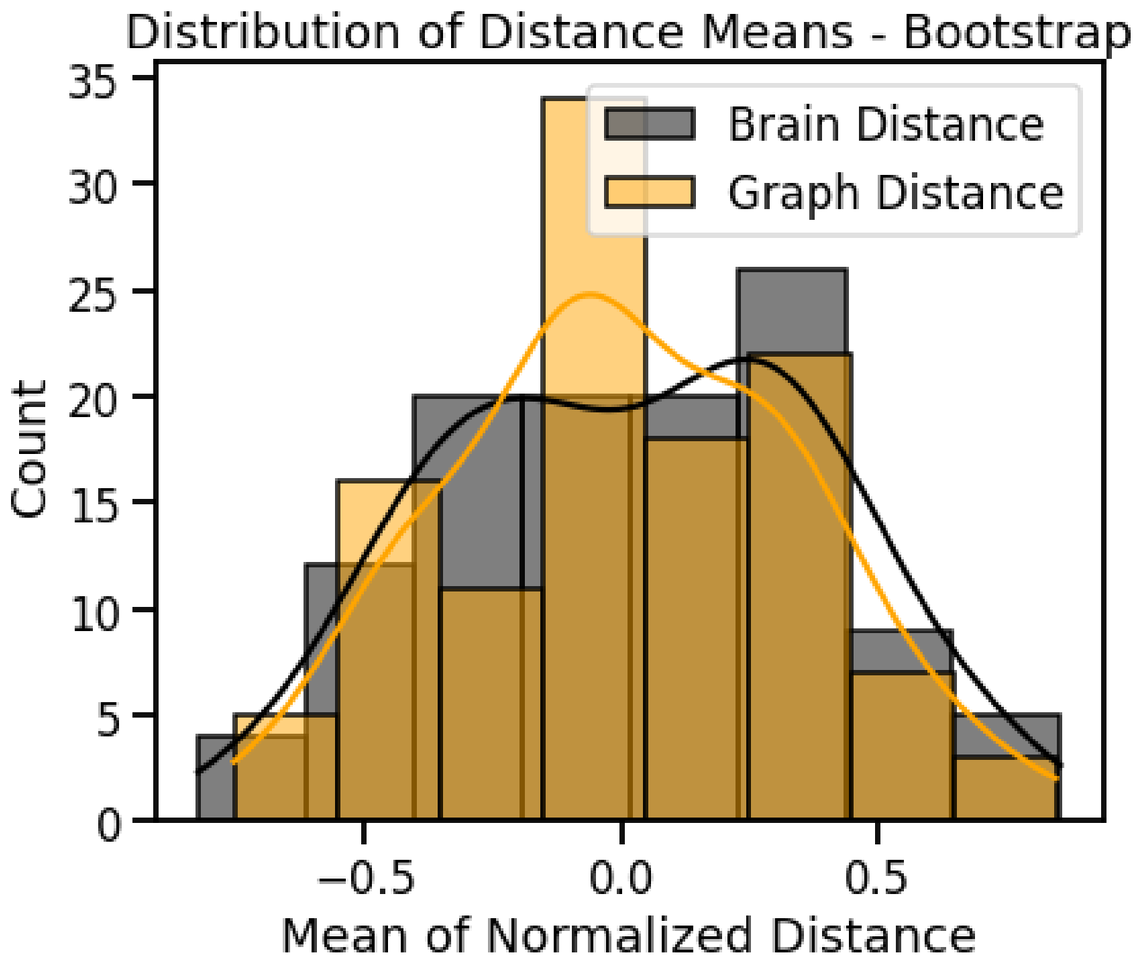


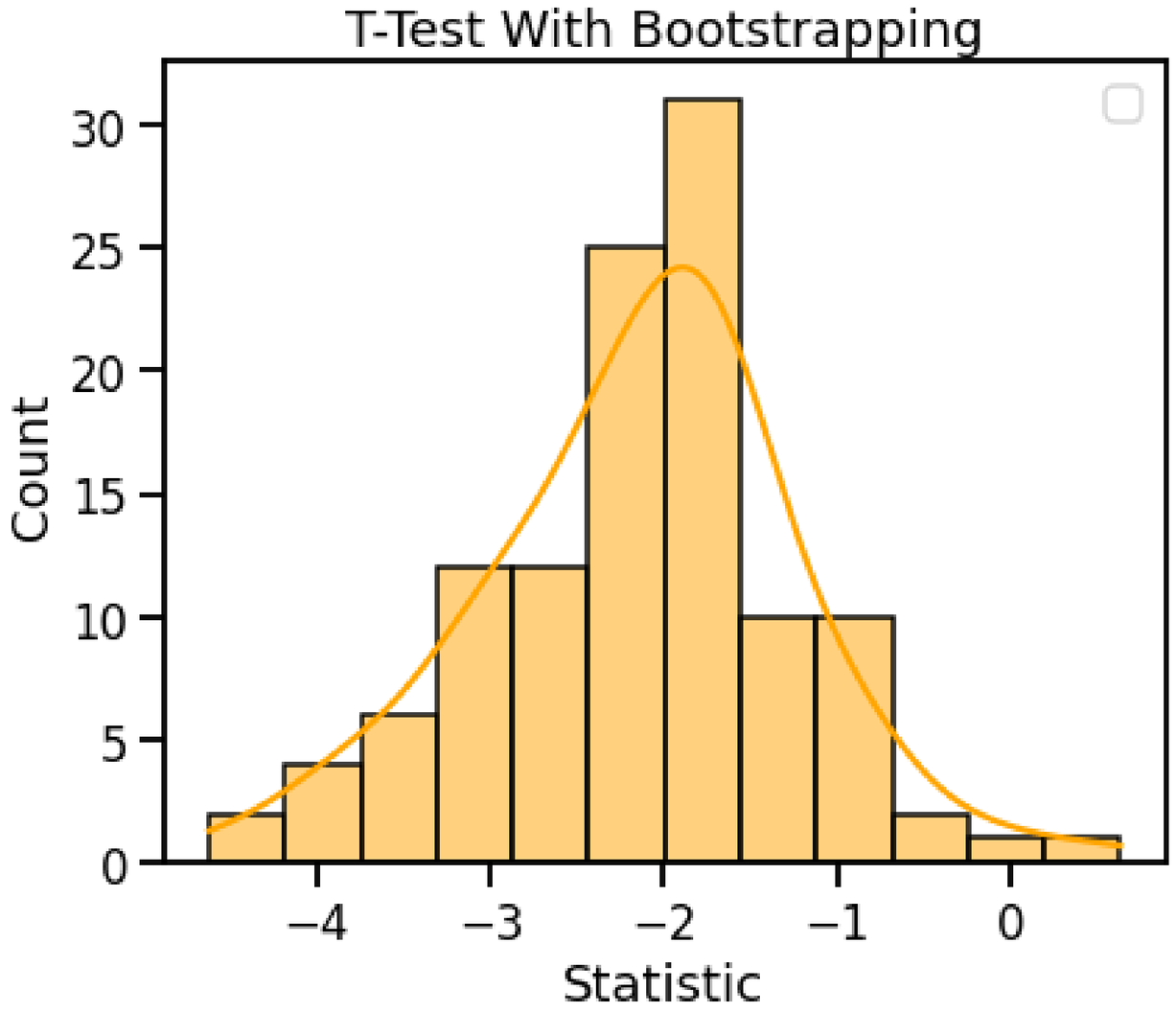
Graph Distances (calculated)




Scatter plot
fit
Data
Real Distance
Graph Distance
3
2
1
0
−1
−2
0
5
10


Distance Distributions
Brain Distance
Graph Distance
Count
200
150
100
50
0
−2.5
0.0
2.5
5.0
7.5
10.0
12.5
Normalized Distance


Distribution of Distance Means - Bootstrap
Brain Distance
Graph Distance
Count
35
30
25
20
15
10
5
0
−0.5
0.0
0.5
Mean of Normalized Distance



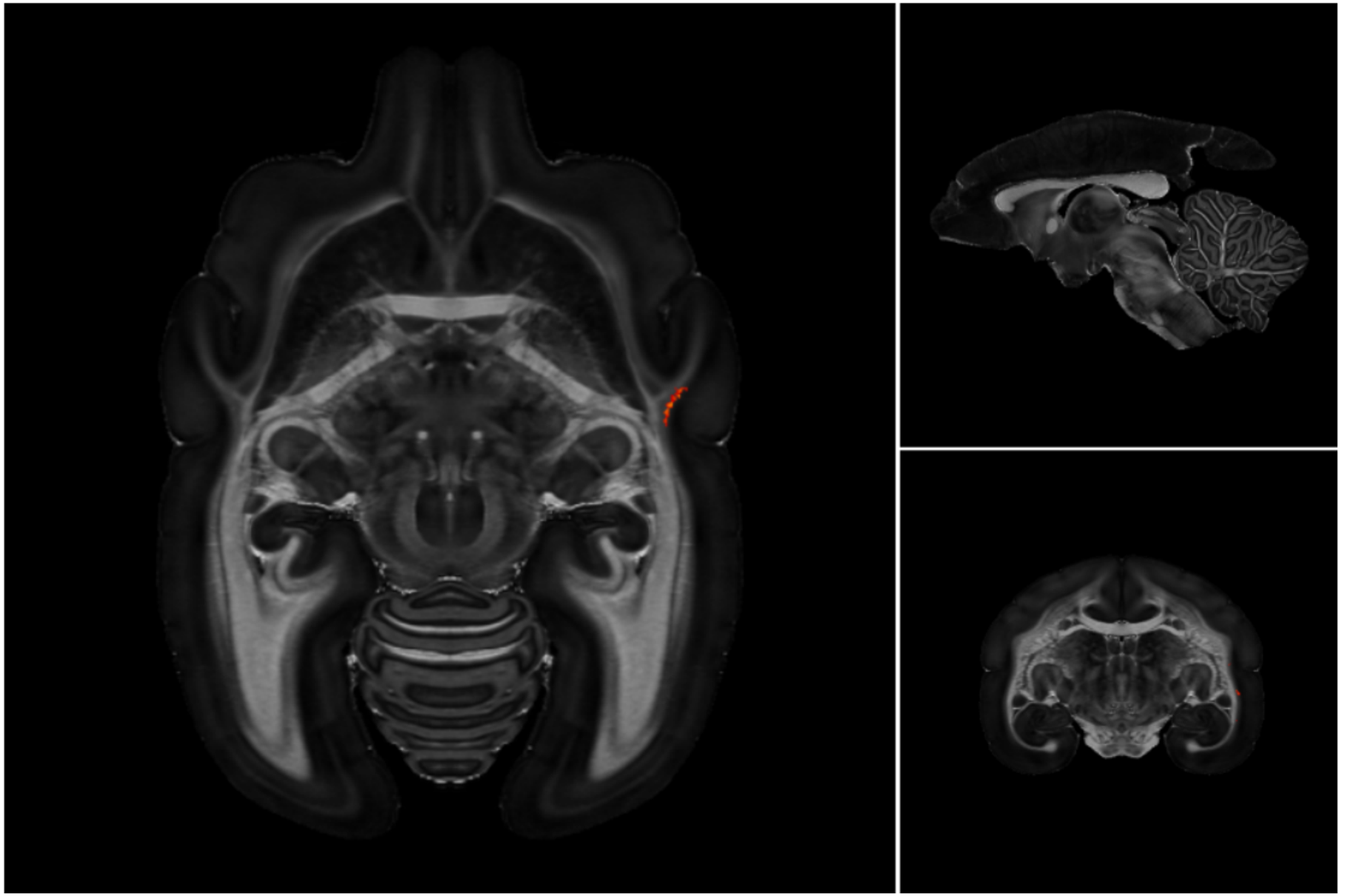
T-test statistic (all data) = -23
p_value = 0

Strength Connection

Area 1	Area 2	Connection (log(FLNe))	In the same Community	Shortest Path = 1
TPO	TE3	-1.3	**Yes**	**Yes**
A23b	**PG**	-1.62	**No**	**Yes**
TE3	**PG**	-1.66	**No**	**Yes**
A23b	A8b	-1.96	**No**	**Yes**
TPO	**PG**	-2.81	**No**	**Yes**
A8b	**PG**	-3.16	**No**	**Yes**
TPO	A8b	-3.26	**Yes**	**Yes**
TE3	A23b	-4.36	**No**	**Yes**

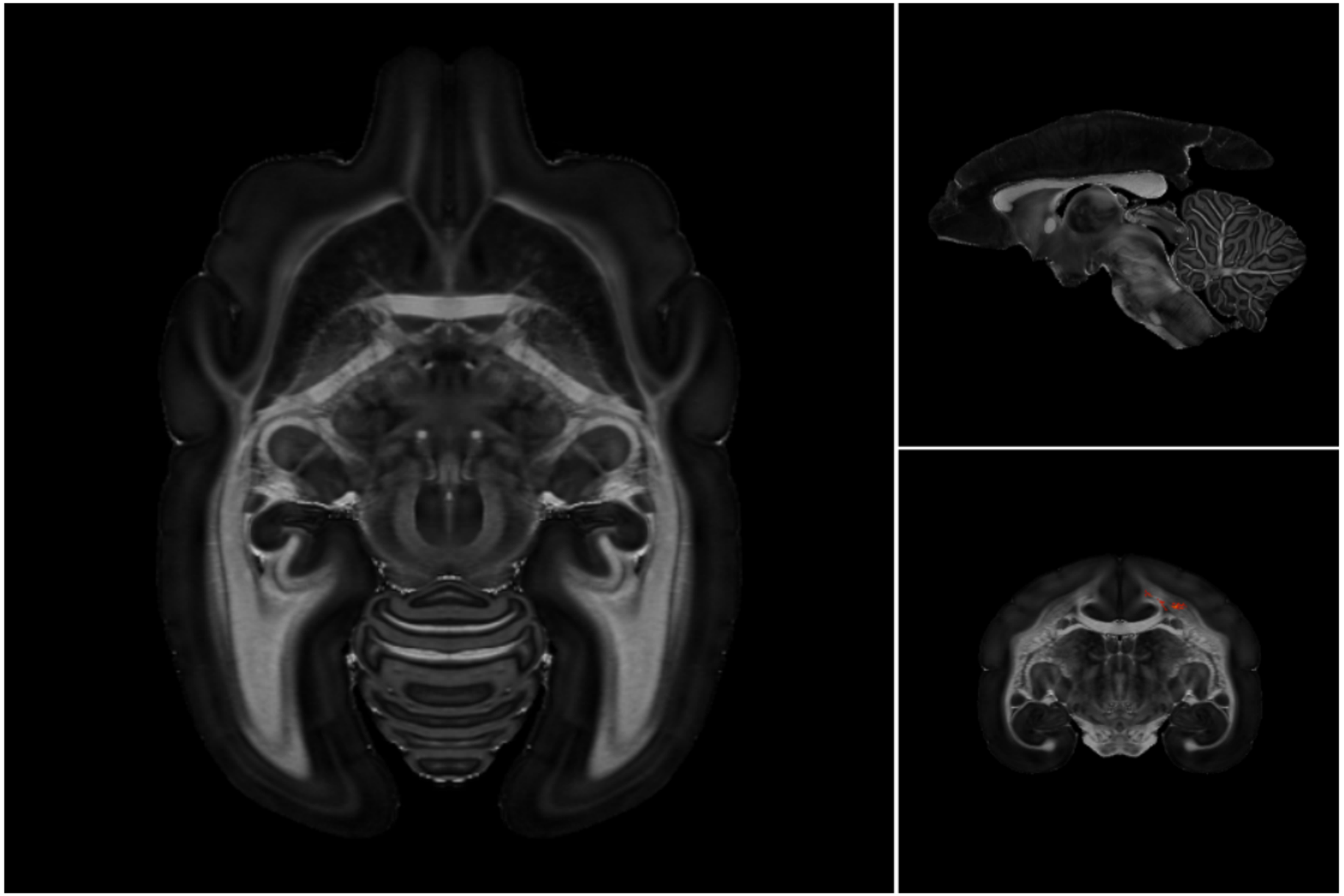
*

Avg path lenght: 1.6

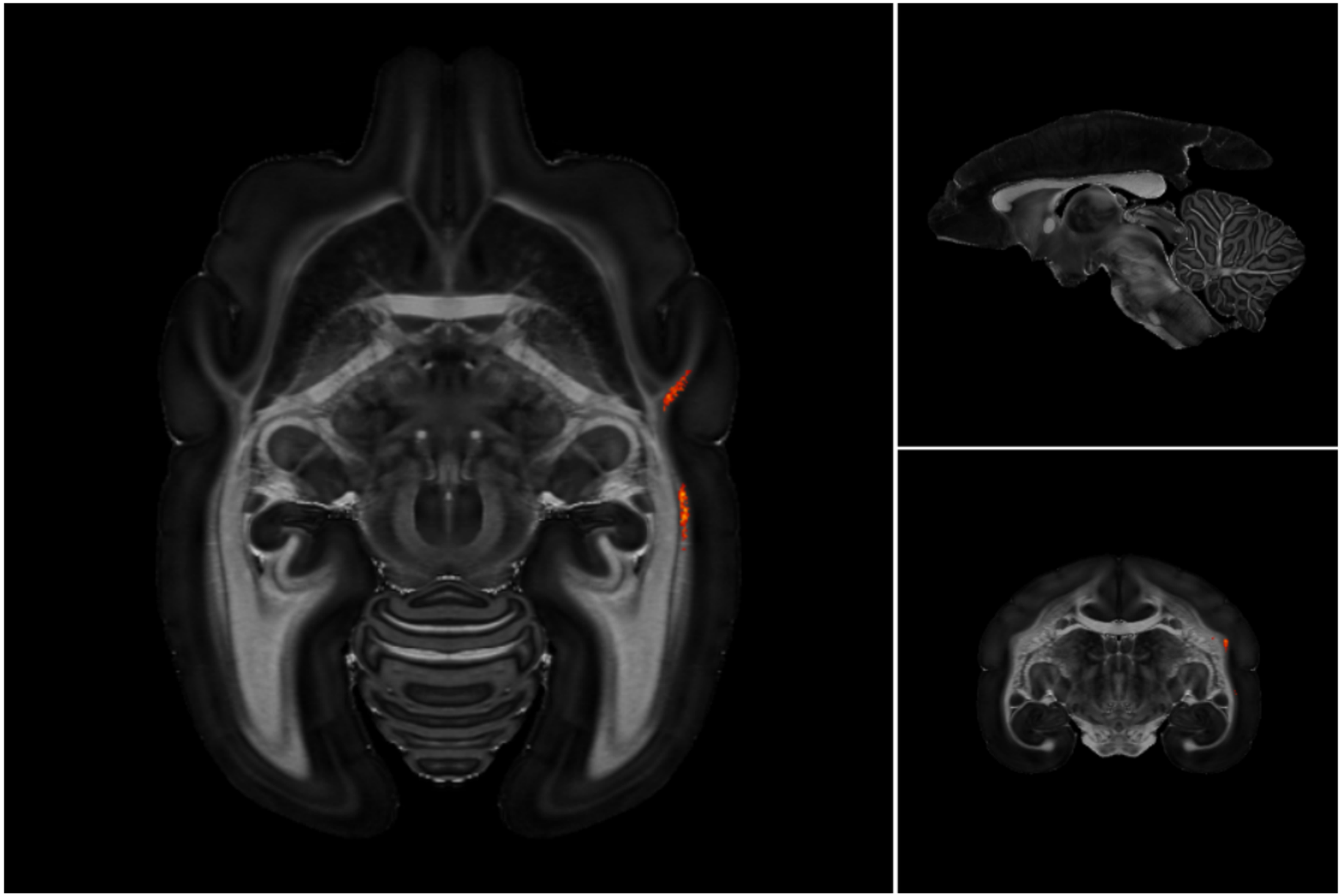


TPO-TE3

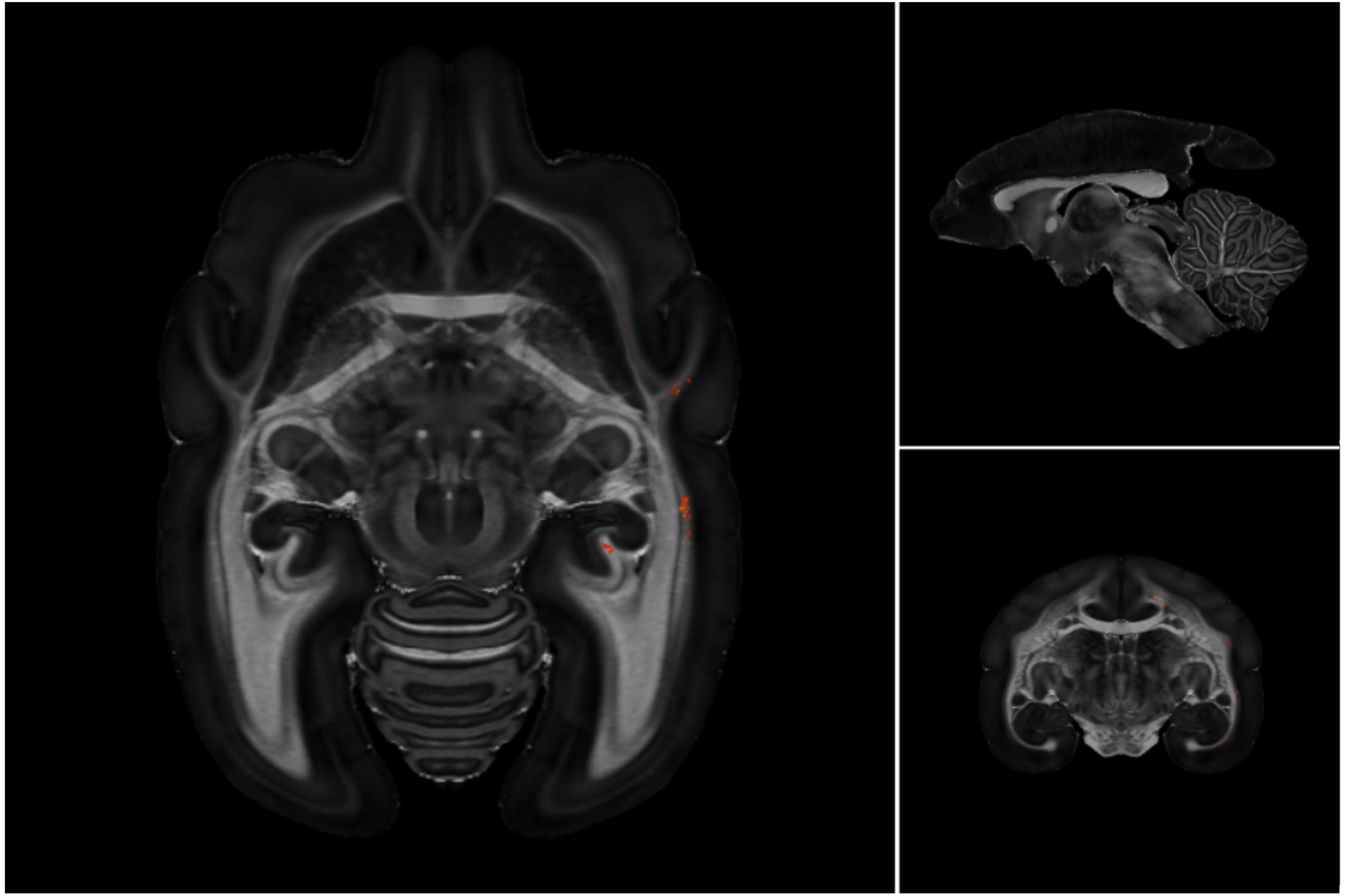
Link



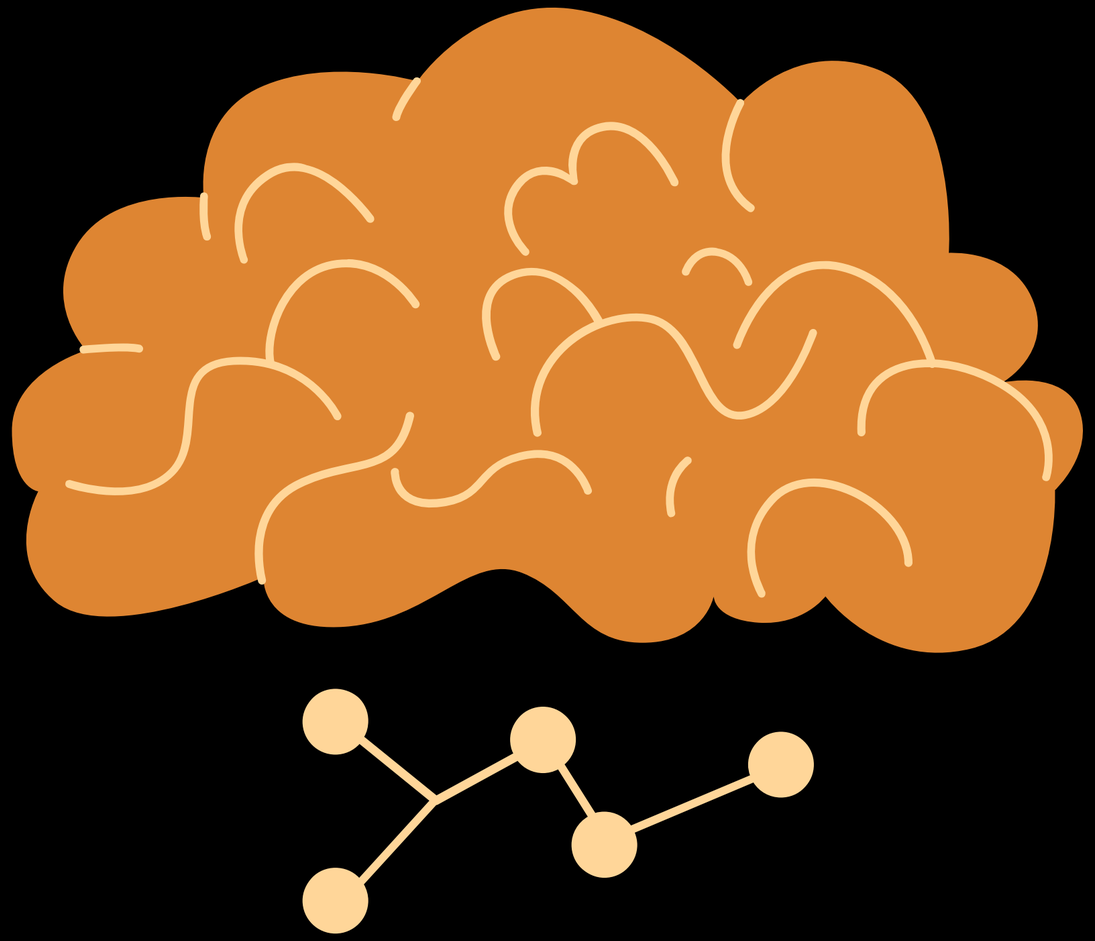
A23b-PG



TE3-PG



A23b-TE3



Conclusion

Constructing connectome network graphs is not that close of an approximation of brain areas taken by proximity.

Networks prioritize functionality over topology.

Closely located areas don't necessarily have the strongest connection.

Limitations

Data accesibility.

Not a lot of structural information.

Lack of time to work with experiment data.

Time to compare between-species.

Github

That's all, folks!

Thank you!

Resources

1. Majka, P., Bai, S., Bakola, S., Bednarek, S., Chan, J. M., Jermakow, N., ... & Rosa, M. G. (2020). Open access resource for cellular-resolution analyses of corticocortical connectivity in the marmoset monkey. Nature communications, 11(1), 1-14.
2. Majka P., Chaplin T.A., Yu, H.-H., Tolpygo A., Mitra P.P., Wójcik D.K., & Rosa M.G.P. (2016). Towards a comprehensive atlas of cortical connections in a primate brain: Mapping tracer injection studies of the common marmoset into a reference digital template. Journal of Comparative Neurology, 524(11), 2161–2181. http://doi.org/10.1002/cne.24023
3. Liu, C., Ye, F.Q., Newman, J.D. et al. A resource for the detailed 3D mapping of white matter pathways in the marmoset brain. Nat Neurosci 23, 271–280 (2020). https://doi.org/10.1038/s41593-019-0575-0
4. Kaas, J. H. (2020). Comparative Functional Anatomy of Marmoset Brains. ILAR Journal, 61(2–3), 260–273. Oxford University Press (OUP). Retrieved from http://dx.doi.org/10.1093/ilar/ilaa026