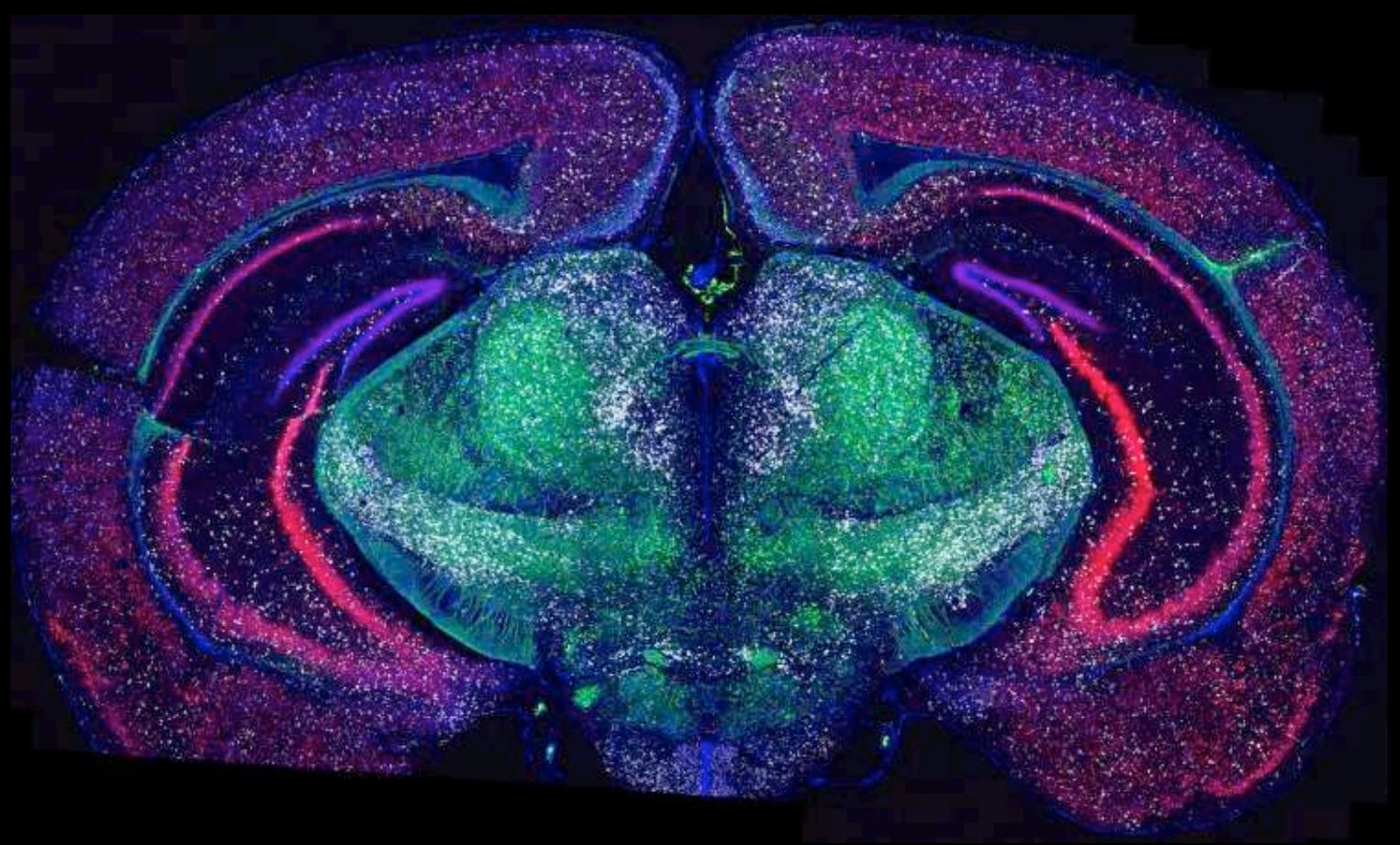

Student Guide to the Neuroinformatics Lab

Version 1.1 Spring 2024

NYU | TANDON

Menu

- PhD requirements
- Research projects
- Fellowships
- Lab organization
- Diversity statement
- Available collaborations
- Expectations
- Typical timeline

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PhD requirements

- **Breadth course requirement** - intended to ensure broad knowledge of computer science

- **Depth requirement** - oral qualifying exam presentation with a written report, to ensure the student's ability to do research

- **Thesis proposal** - Written report + oral presentation about the proposal

- **Thesis** - Written dissertation that must be approved by a dissertation guidance committee + oral defense

- **Credit requirements** - 75 total credits needed, 24 of which must come from courses (each course is 3-4 credits)

Breadth course requirement - “Do you know general topics in CS?”

- 4 courses from the approved list of courses:
    - At least 1 theory
        - Design and Analysis of Algorithms II CS-GY 6043 (If not already taken previously)
        - Algorithmic Machine Learning and Data Science CS-GY 6763 (If algorithms II already taken)
    - At least 2 applications
        - Computer Vision CS-GY 6643 **(Taught by me - offerred in fall only)**
        - Machine Learning CS-GY 6923
        - Deep Learning CS-GY 6953
        - Neuroinformatics CS-GY 9223 **(Lab course - offerred in spring only)**
- 2 “free choice” courses (suggested ones below)
        - Computational Neuroscience NEURL-GA 3042
        - Bioinformatics and Genomes BIOL-GA 1127
- Caveats: A or A- in a graduate course at another university with standards comparable to those at NYU, can use that course in lieu of taking the course on the approved list.
- Equivalent courses can be taken in any of the NYU schools i.e. CAS, CDS or Courant.

Doctoral Degrees Without Borders

PhD candidates from nine northeast universities will soon be able to take engineering courses across campuses

NOV 09 2023

You can take courses at nearby engineering schools after year 1

Together with NYU Tandon, IUEDC participants are:

- The City College of New York's Grove School of Engineering (New York, NY)
- Columbia Engineering (New York, NY)
- Cornell Tech (New York, NY)
- New York Institute of Technology College of Engineering and Computing Sciences (Old Westbury, NY, and New York, NY)
- Princeton University School of Engineering and Applied Science (Princeton, NJ)
- Rutgers University School of Engineering (Piscataway, NJ)
- Stevens Institute of Technology Charles V. Schaefer Jr. School of Engineering and Science (Hoboken, NJ)
- Stony Brook University College of Engineering and Applied Sciences (Stony Brook, NY)

To participate, students must have completed at least one year at their primary institution, must be in good academic standing and must get written approval from home and host institutions. Students will be responsible to their host institutions for any lab fees.

Depth requirement - “can you do research?”

- **Must be done before end of year 2**
- oral qualifying exam presentation
  - Must make a presentation about “original” research
  - Written report about research
- 30 minutes oral examination about coursework topics

Thesis proposal - “do you have a coherent research story?”

- Typically done in year 4.

- Must form a thesis commitee of >3 faculty (ideally 1 external)

- Written report that outlines research aims

- Oral presentation to thesis committee (45 minutes)

Thesis - “Have you generated new knowledge with rigor?”

- Year 5.
- Written dissertation with abstract, intro, chapters and future directions.

- Oral presentation to thesis committee (45 minutes)

Credit requirements - “Have you spent enough time?”

- Total **75 credits** needed
    - 24 course credits (18 will automatically come from breadth requirement)
    - At least 21 dissertation credits
- On average, each semester is about 9 credits (3 courses).
    - 75/18 ~ 9 semesters - 4.5 years of minimum time

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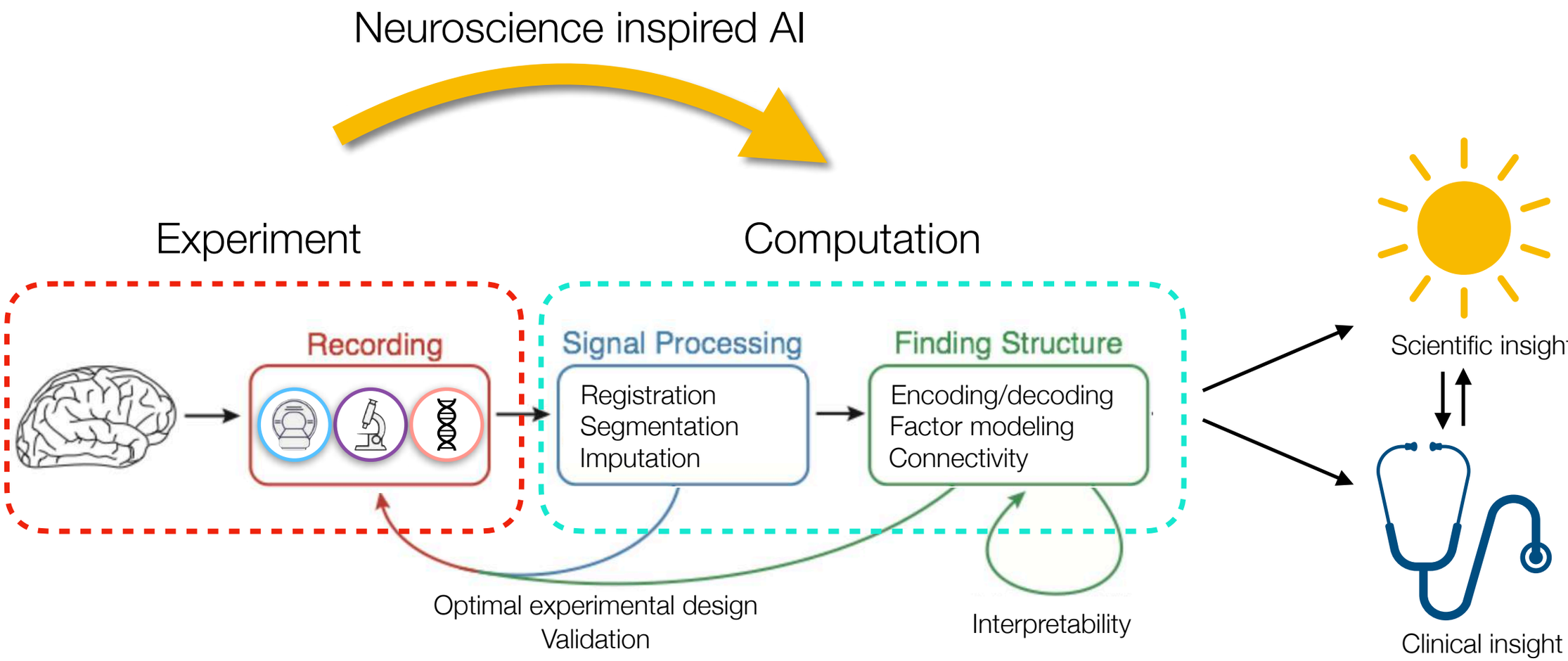
Neuroinformatics: Research projects at the interface of computer science with neuroscience / health informatics



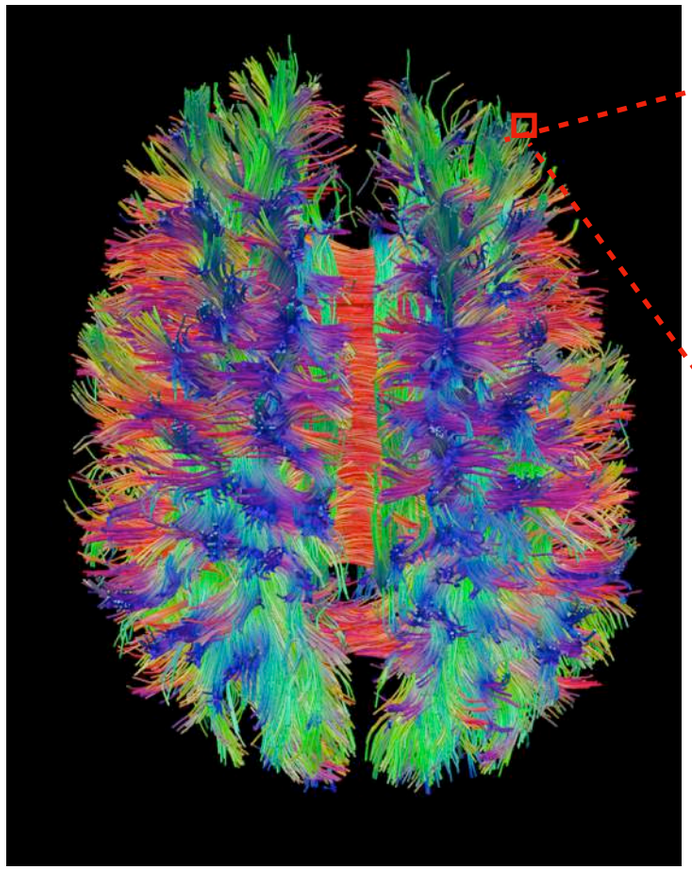
Paninski, Cunningham (Current Opinion in Neurobiology 2018)

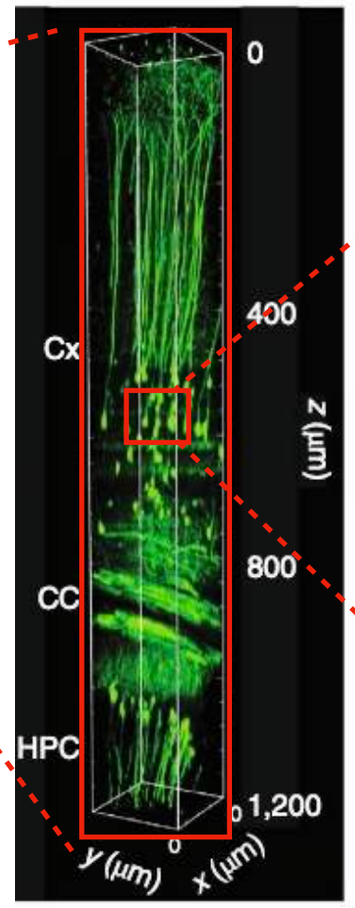
Biomedical data from multiple scales

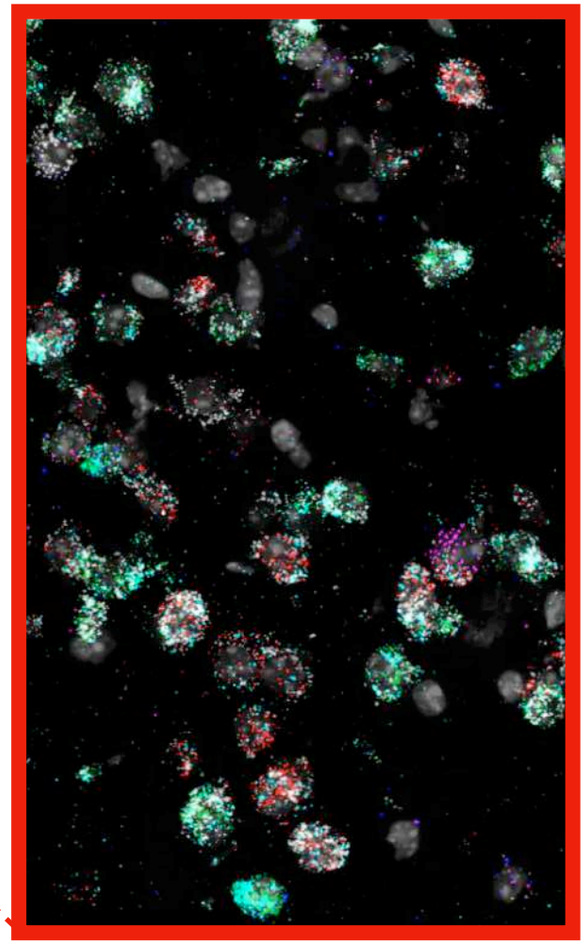
Whole brain

Circuits

Molecules



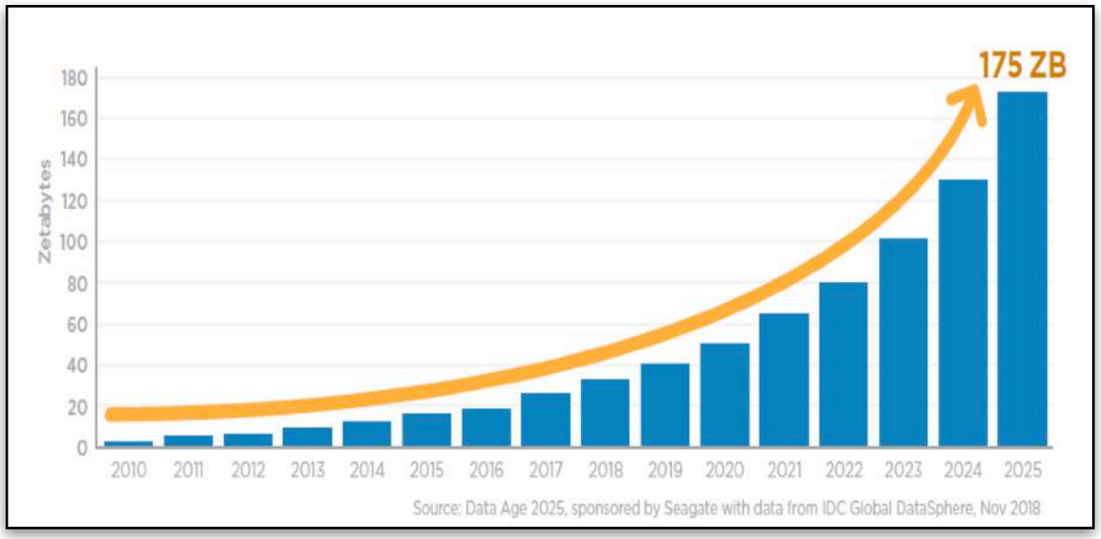


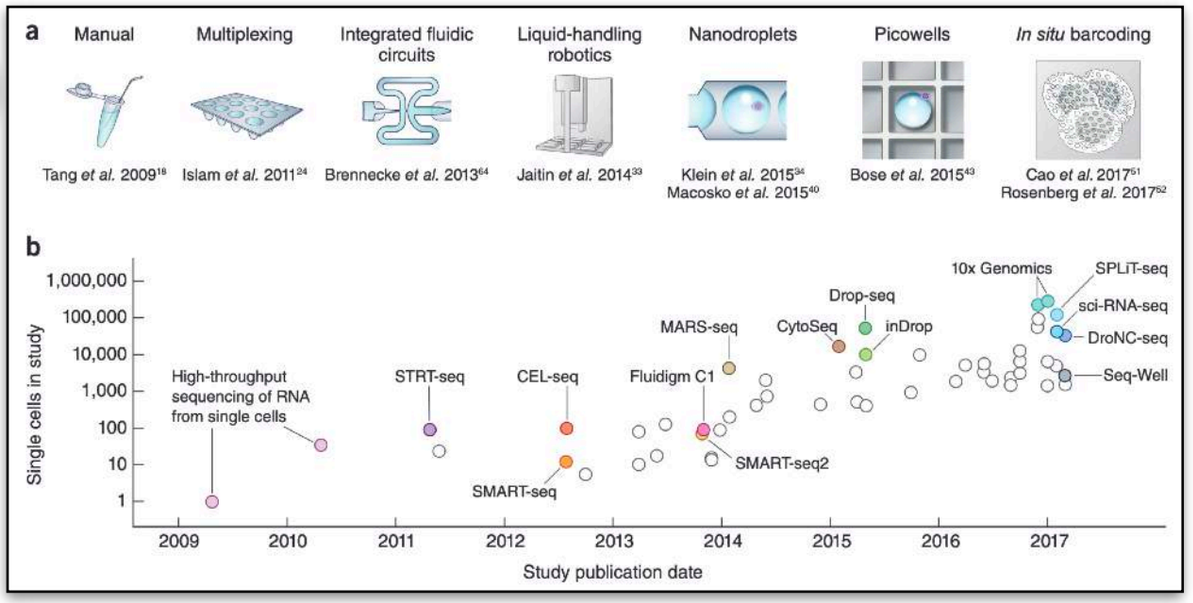


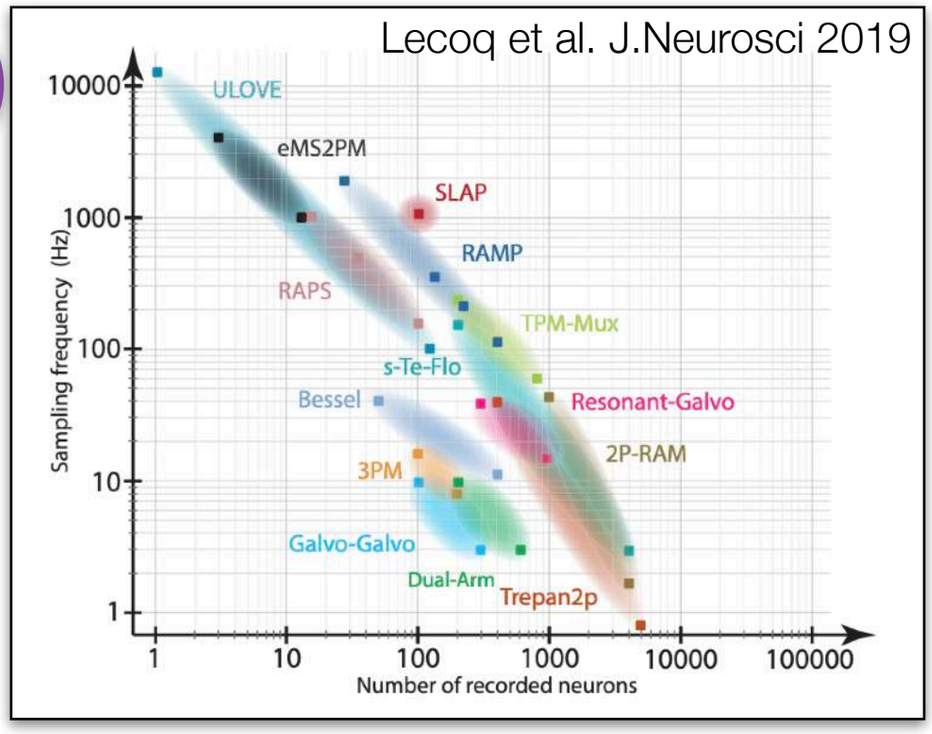
~1mm ~1um ~1nm

Spatial resolution

Too much data! We need to reinvent our toolboxes.







biobank uk

n>500,000

Adolescent Brain Cognitive Development®

Teen Brains. Today's Science. Brighter Future.

n>10,000

HUMAN Connectome PROJECT

n>1200

Specific challenge 1: Heterogeneity

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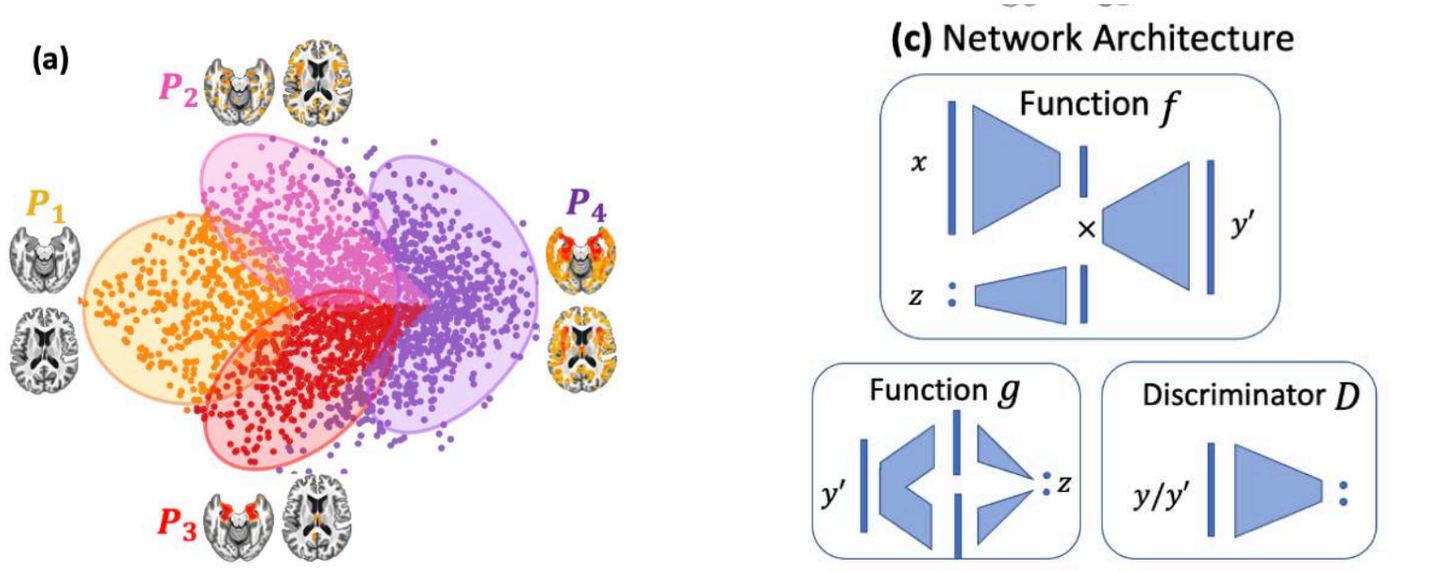
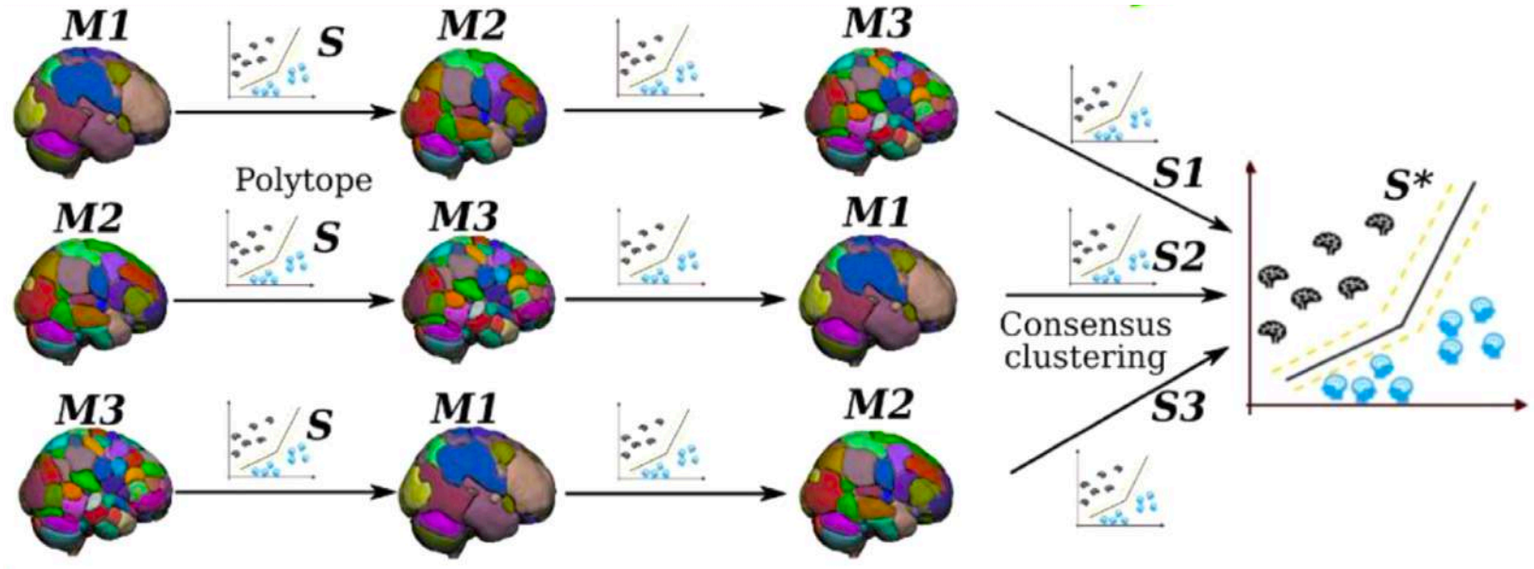
Interpreting the heterogeneity of large scale health records / imaging datasets



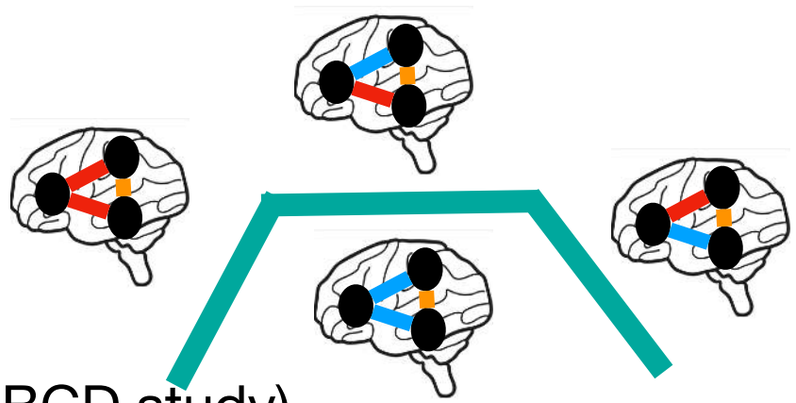
Yang, Wen, Davatzikos (ICLR 2022)

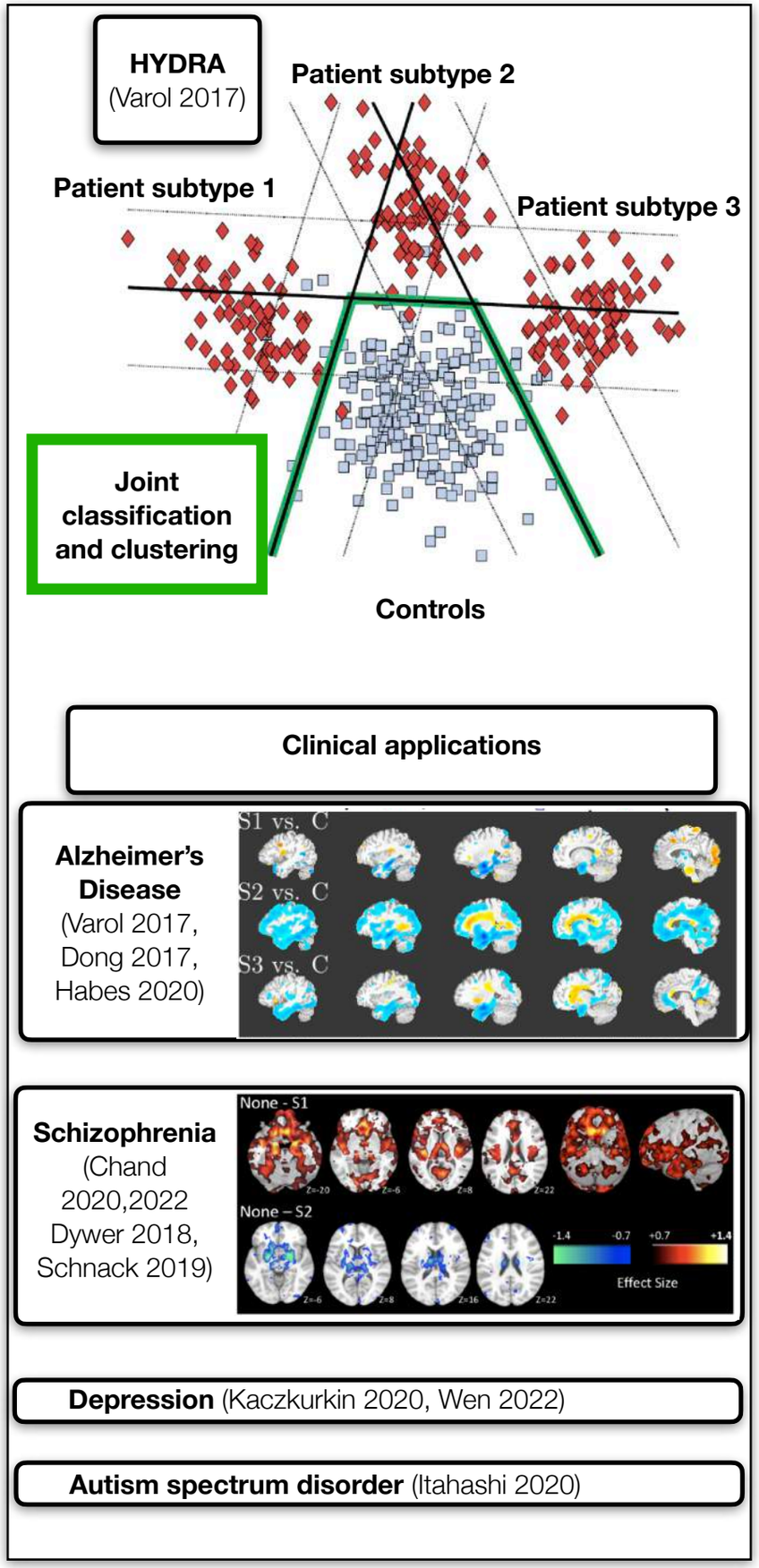


Wen, **Varol** et al. (Medical Image Analysis 2022)

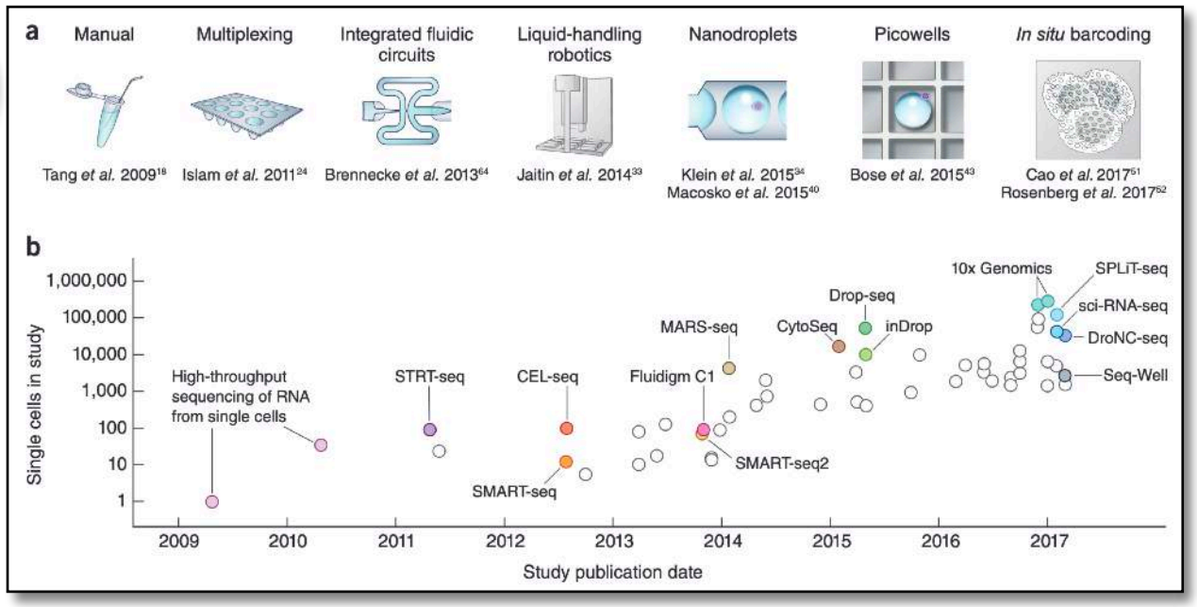
Contributions and future work

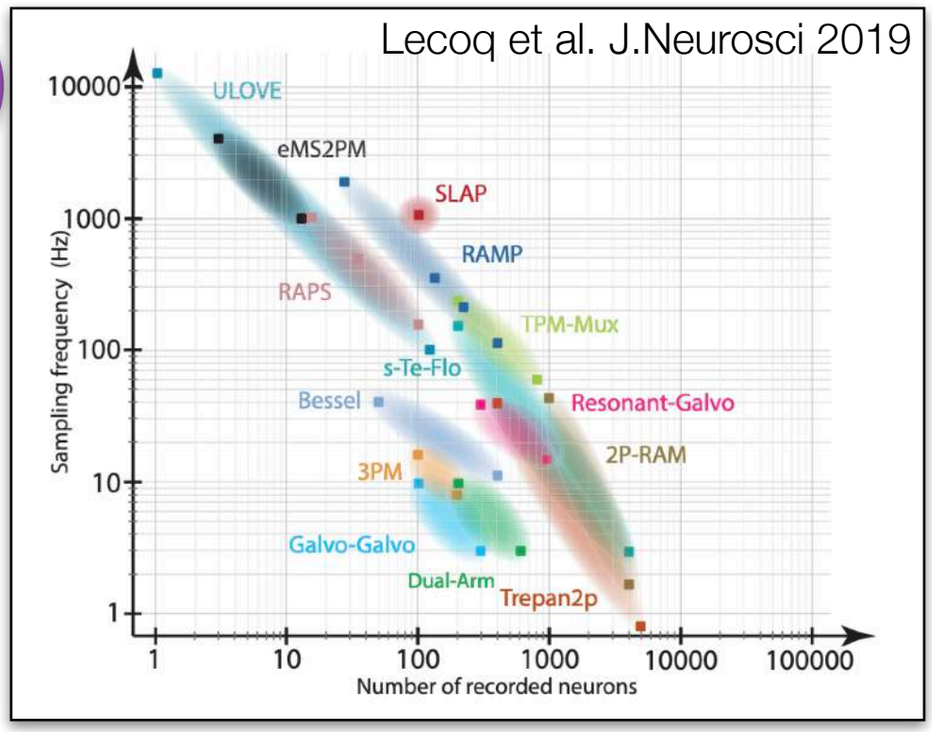
- Novel **supervised clustering** method for parsing heterogeneity.
- **Interpretable non-linearity** with convex polytope decision boundary
- **Discovery of novel subtypes** of neuropsychiatric diseases.
- New **multi-scale** and **non-linear variants.**
- **Future work:**
  - Connectivity
  - Longitudinal data (ABCD study)
  - Digital health records
  - New modalities e.g. EEG and wearables





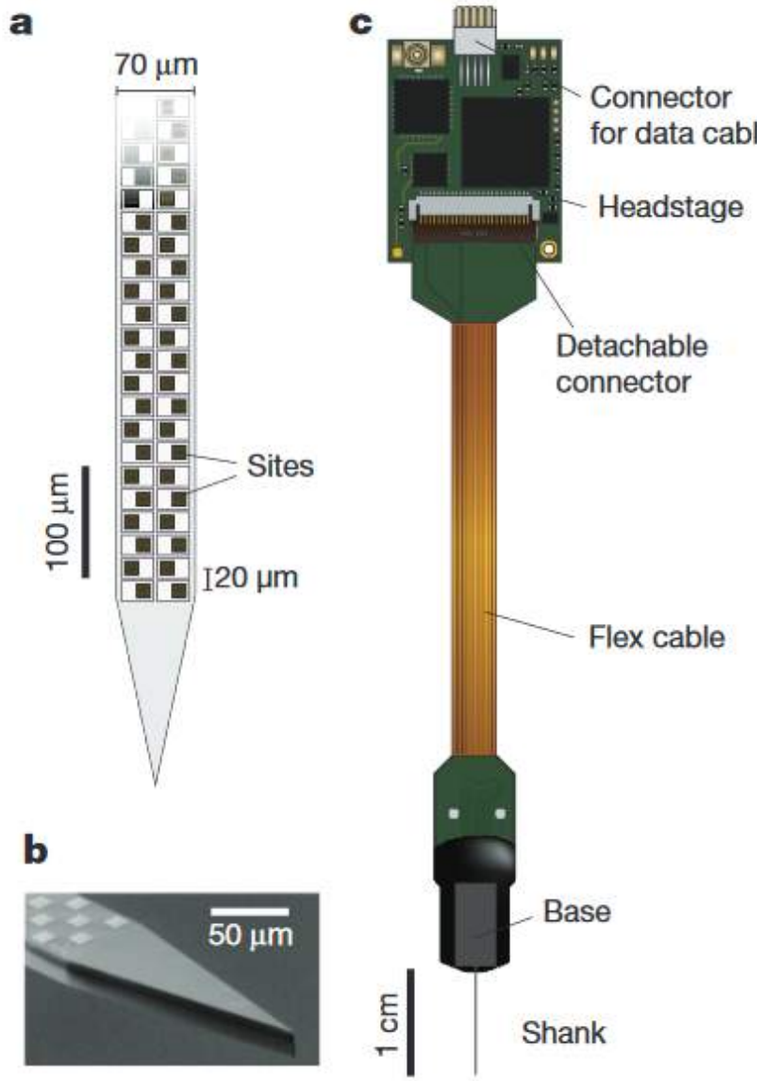
Specific challenge 2: New modalities need new tools



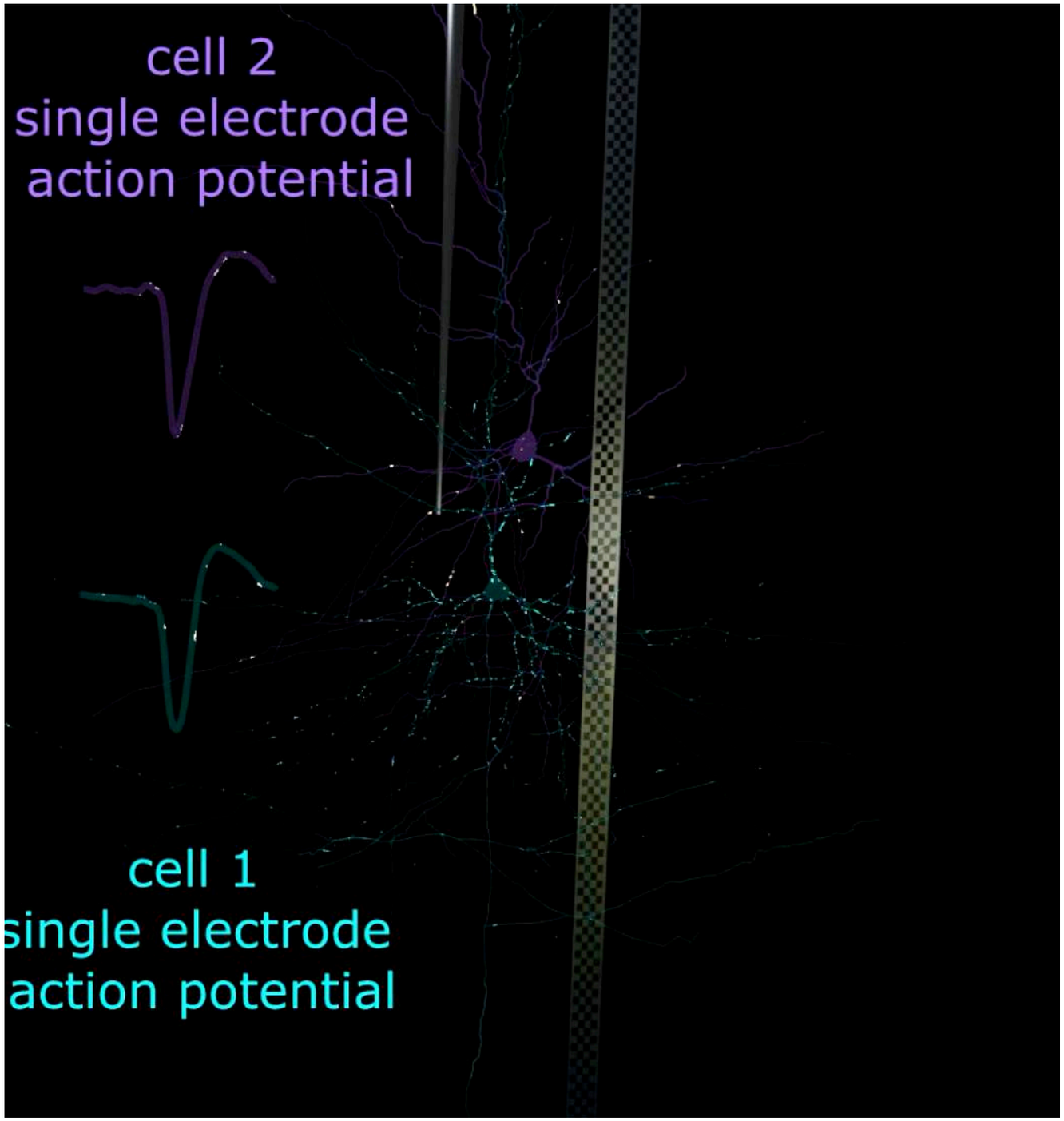


Neuropixels: a high-density electrode array

Electrophysiology at unprecedented spatial resolution



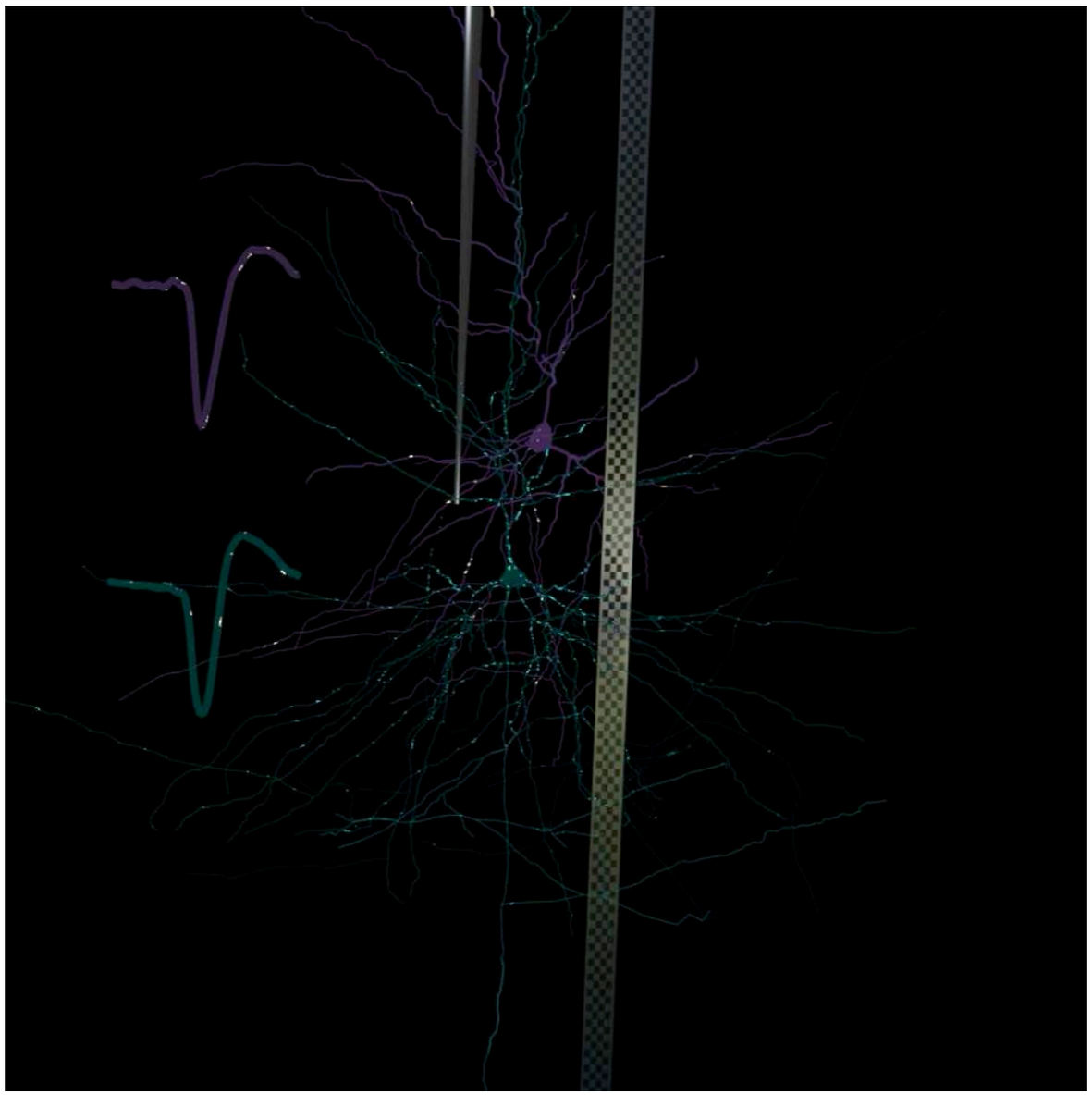
(Windolf,…, **Varol**, 2023)



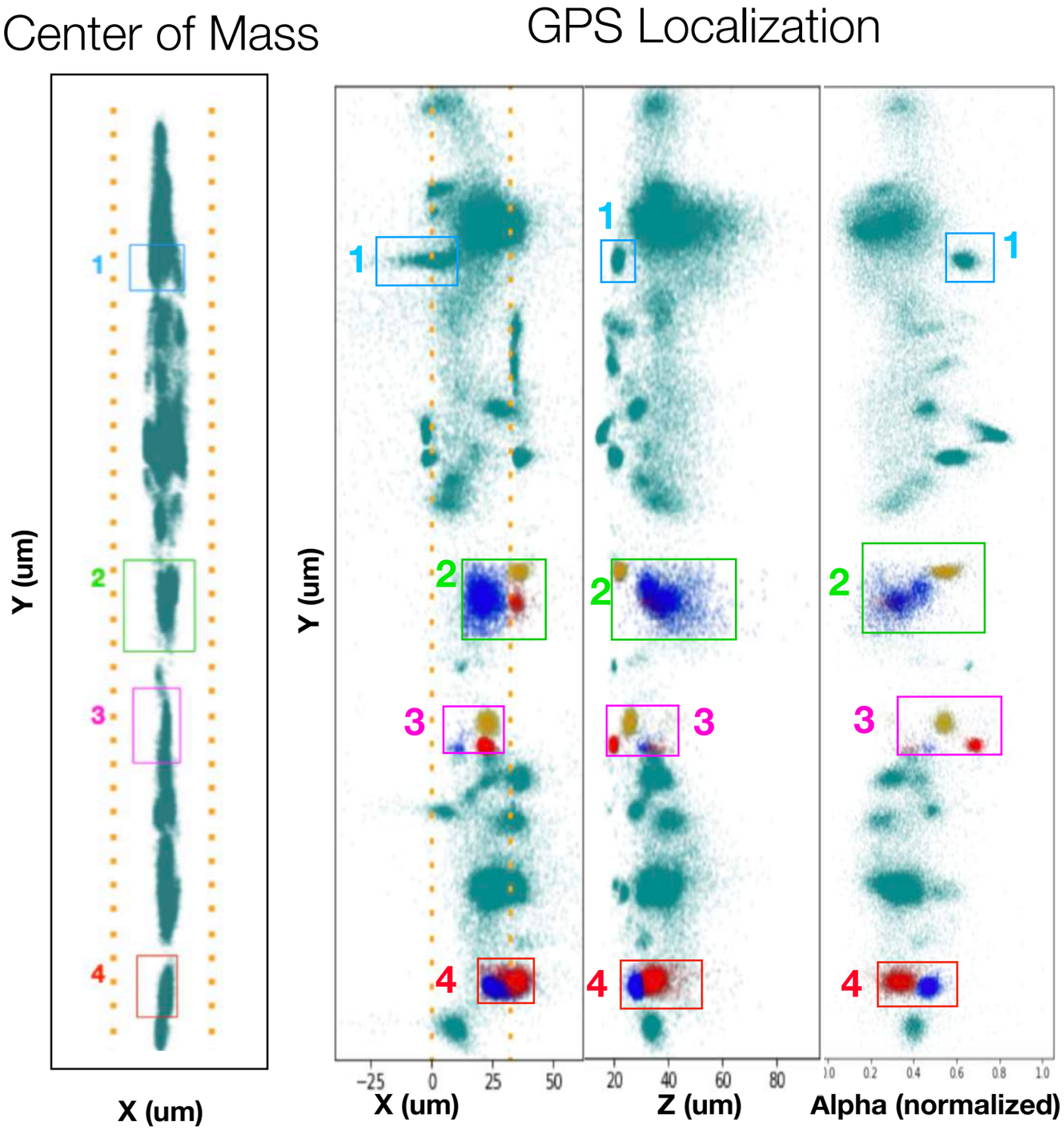
(Animation by A. Paulk / MGH)

J.J. Jun et al. (Nature, 2016)

GPS localization:
Improves signal source separation

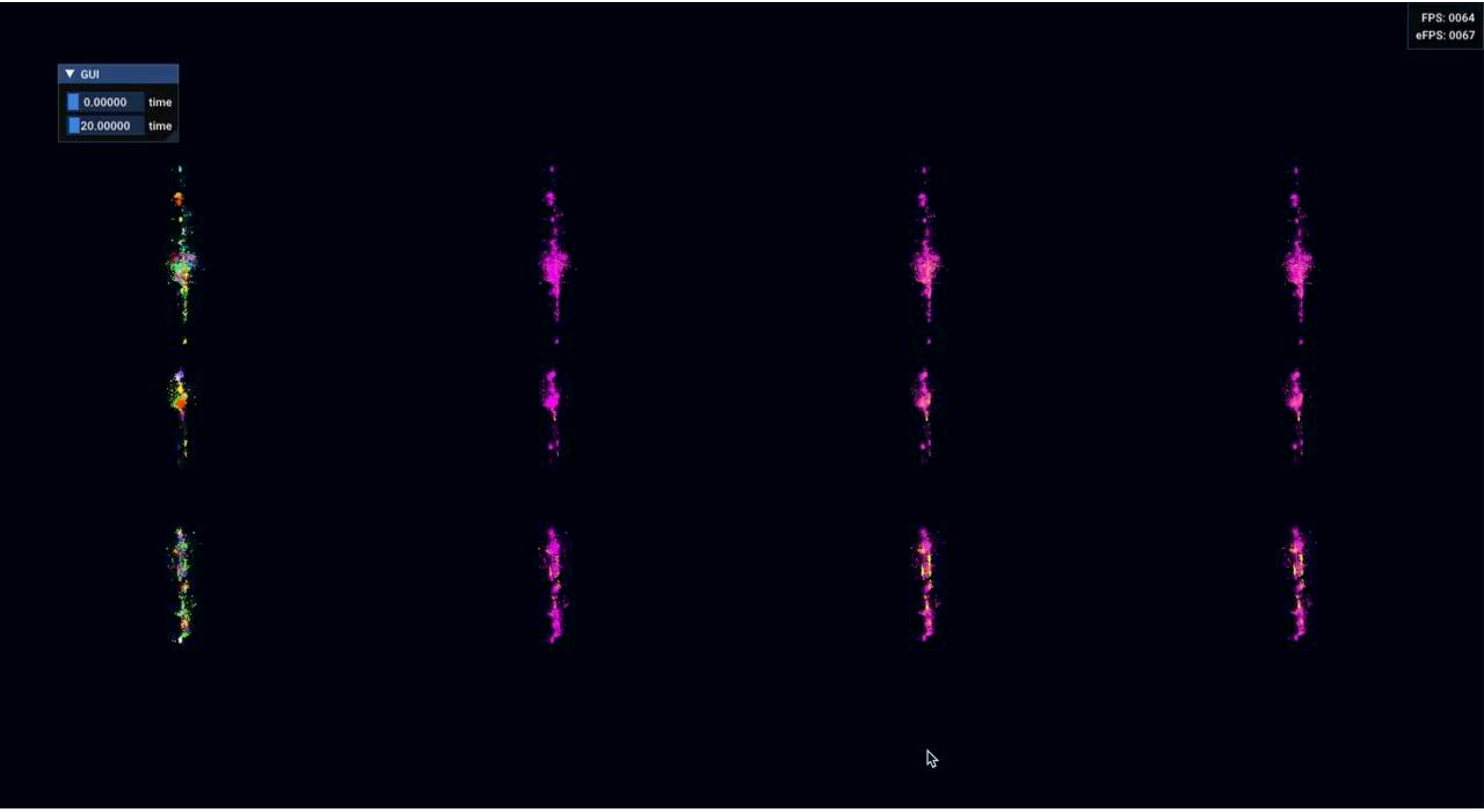


(Animation by A. Paulk / MGH)



Boussard*, **Varol*** et al. (NeurIPS'21)

Efficient visualization of neural circuit morphology



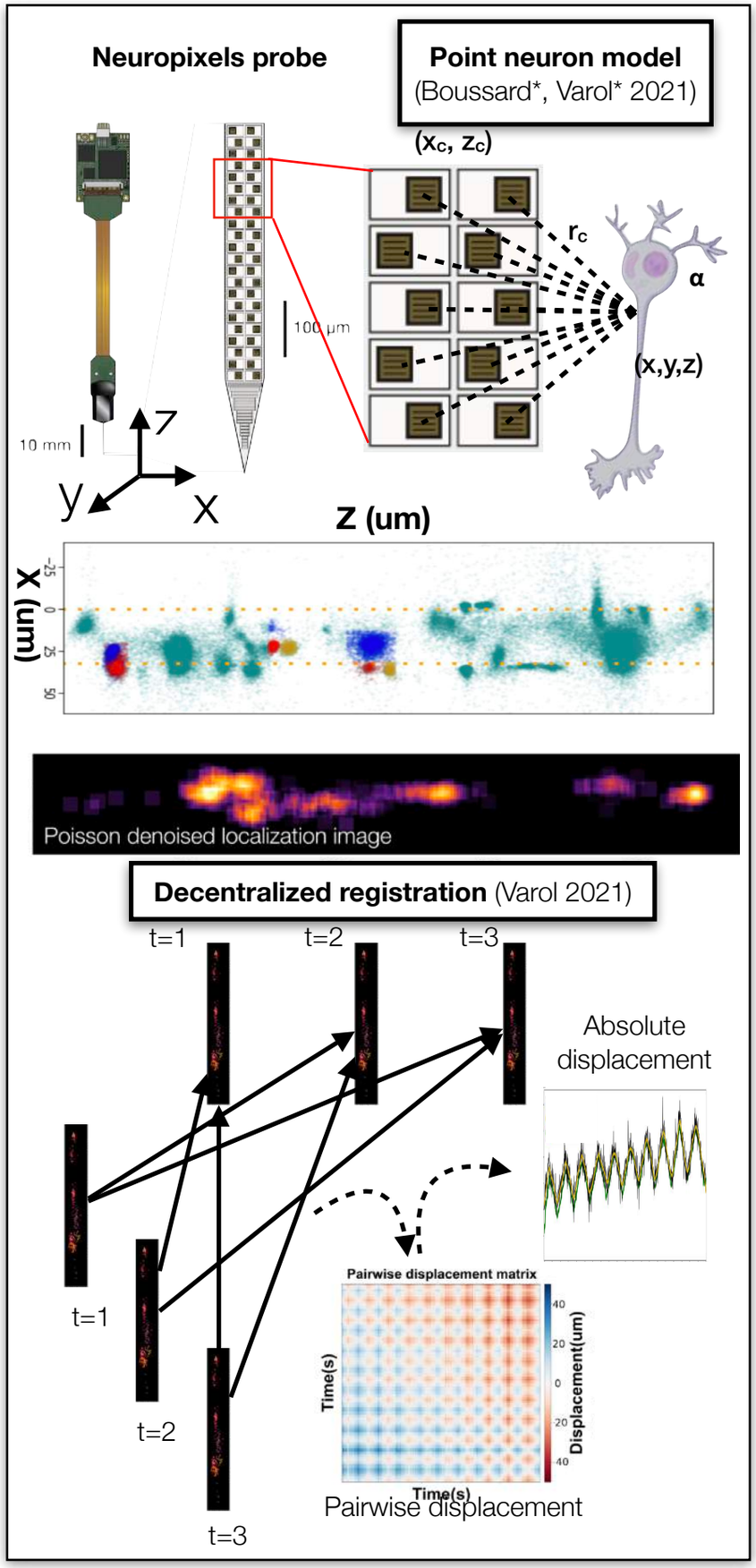
INTERNATIONAL BRAIN LABORATORY

DAT VIZ

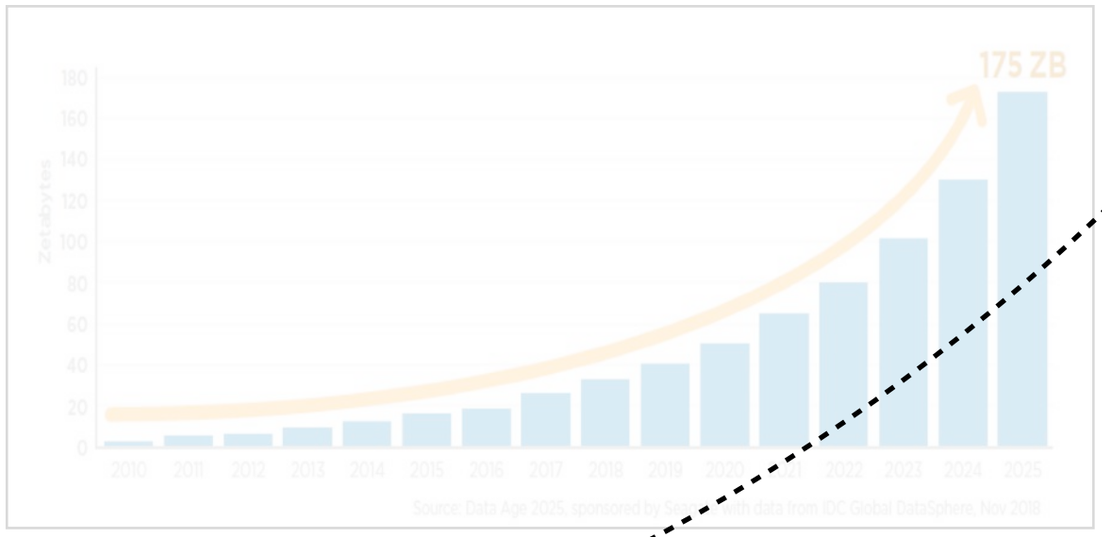
(Credit: Cyrille Rosant @IBL)

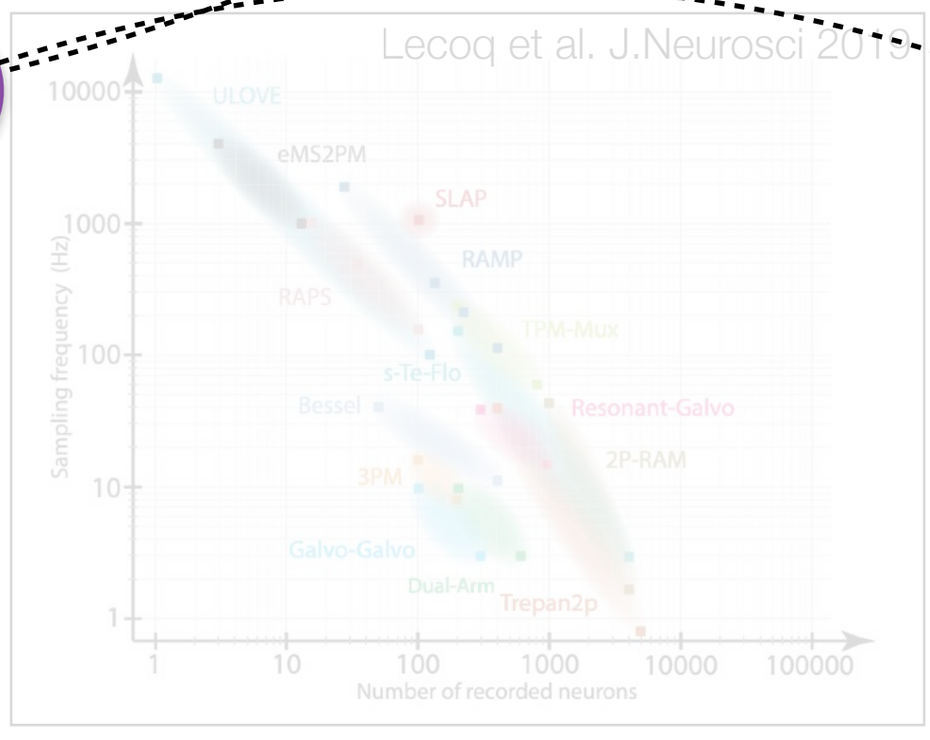
Contributions and future work

- Novel **neural spiking localization** model
- Spatial information improves **segmentation**
- **Image representation** of voltage
- Novel **motion correction** technique with decentralized registration
- Large scale GPU based **visualization**
- **Future work:**
  - **spike sorting**
  - **multi-animal alignment**
  - **task prediction via deep learning**
  - **human trials** (MGH collaboration + Michael Long @ NYU)



Specific challenge 3: Multi-modal integration





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Adolescent Brain Cognitive Development®

Teen Brains. Today's Science. Brighter Future.

n>10,000

HUMAN Connectome PROJECT

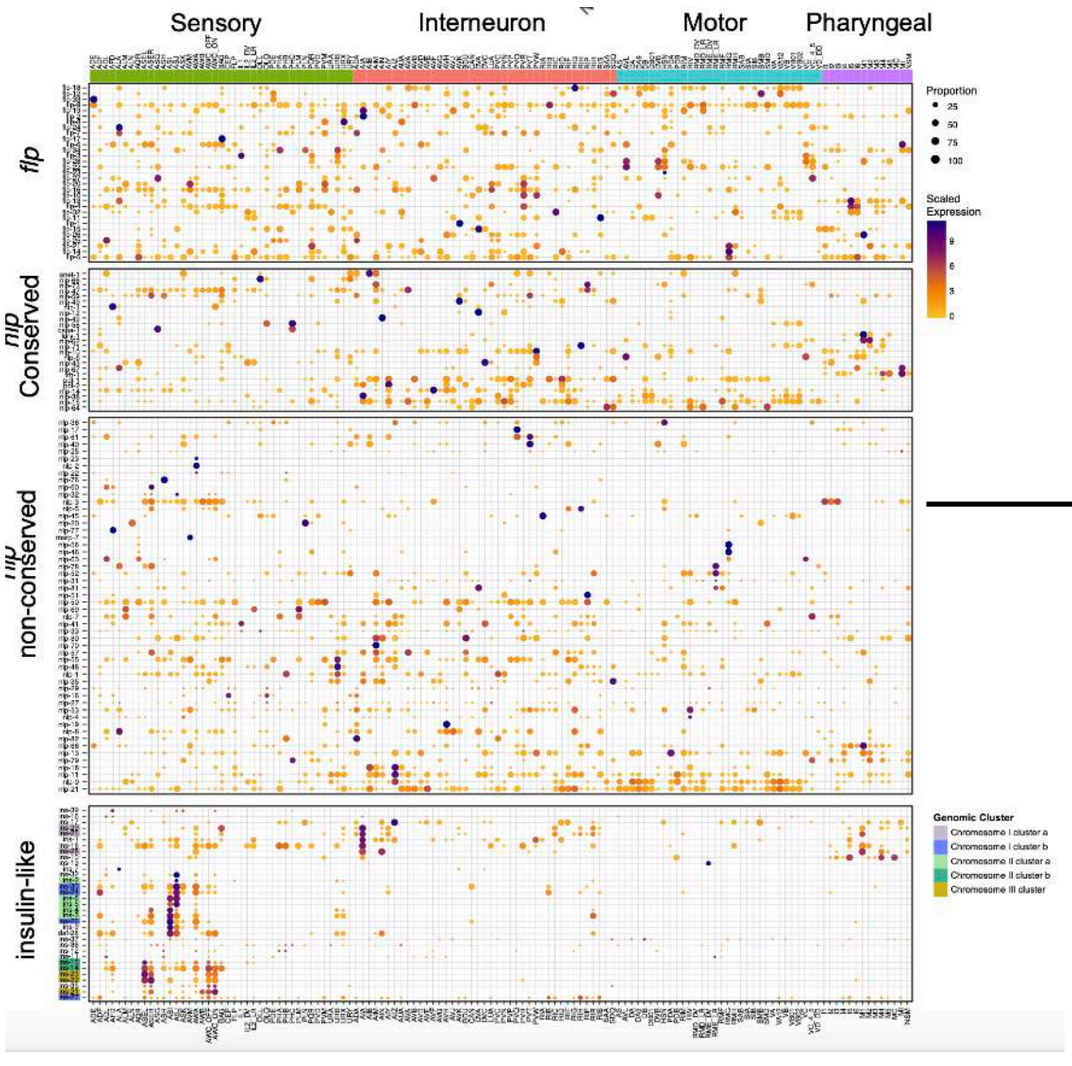
n>1200

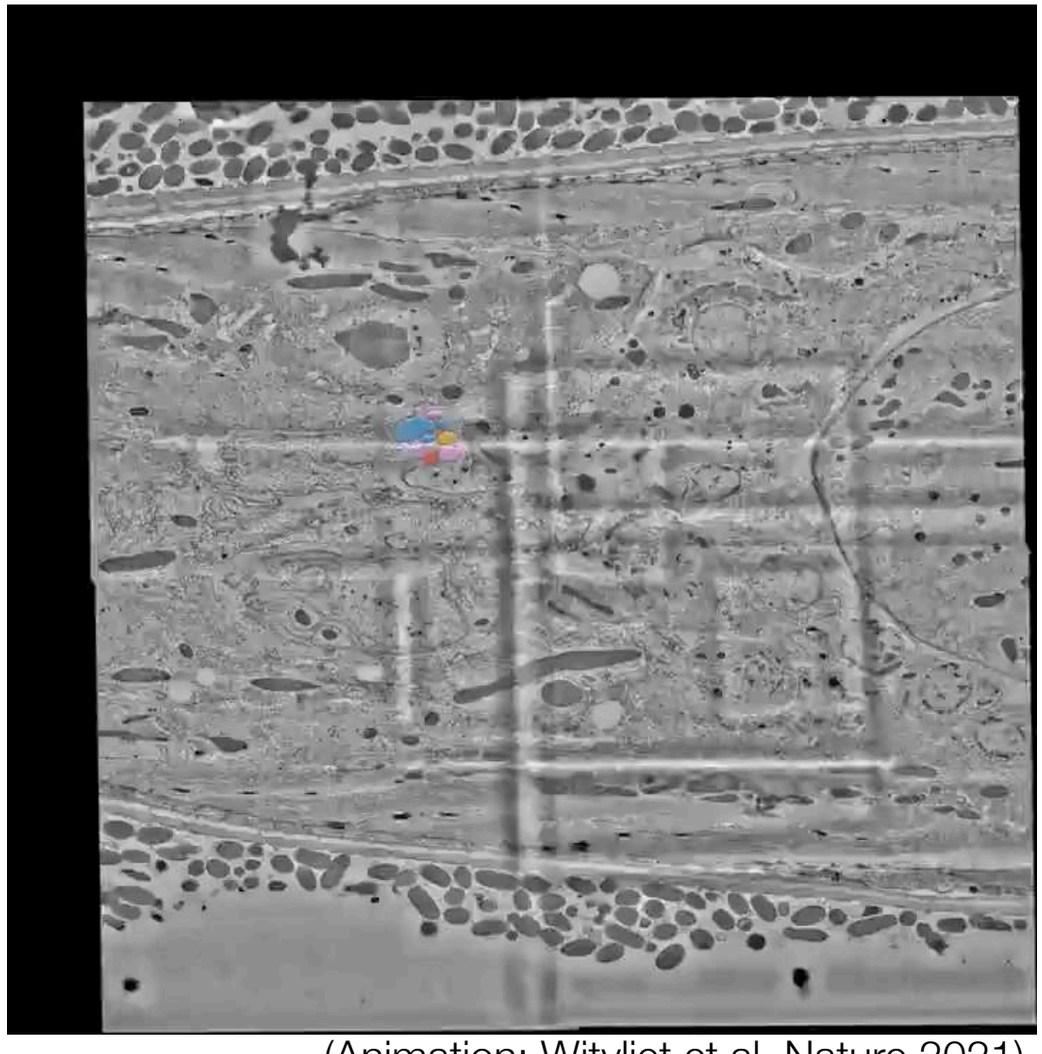
If we measure genetics + brain signals simultaneously, can we relate the two?

?

In *C. Elegans* we can ask a more specific question:

What are the genetic rules of connectivity?





(Animation: Witvliet et al. Nature 2021)

Complete genome

Complete connectome

CeNGEN

Yemini,…,**Varol** et al. 2021 Cell

Taylor,…,**Varol** et al. 2021 Cell

Reilly,…,**Varol** et al. 2020 nature

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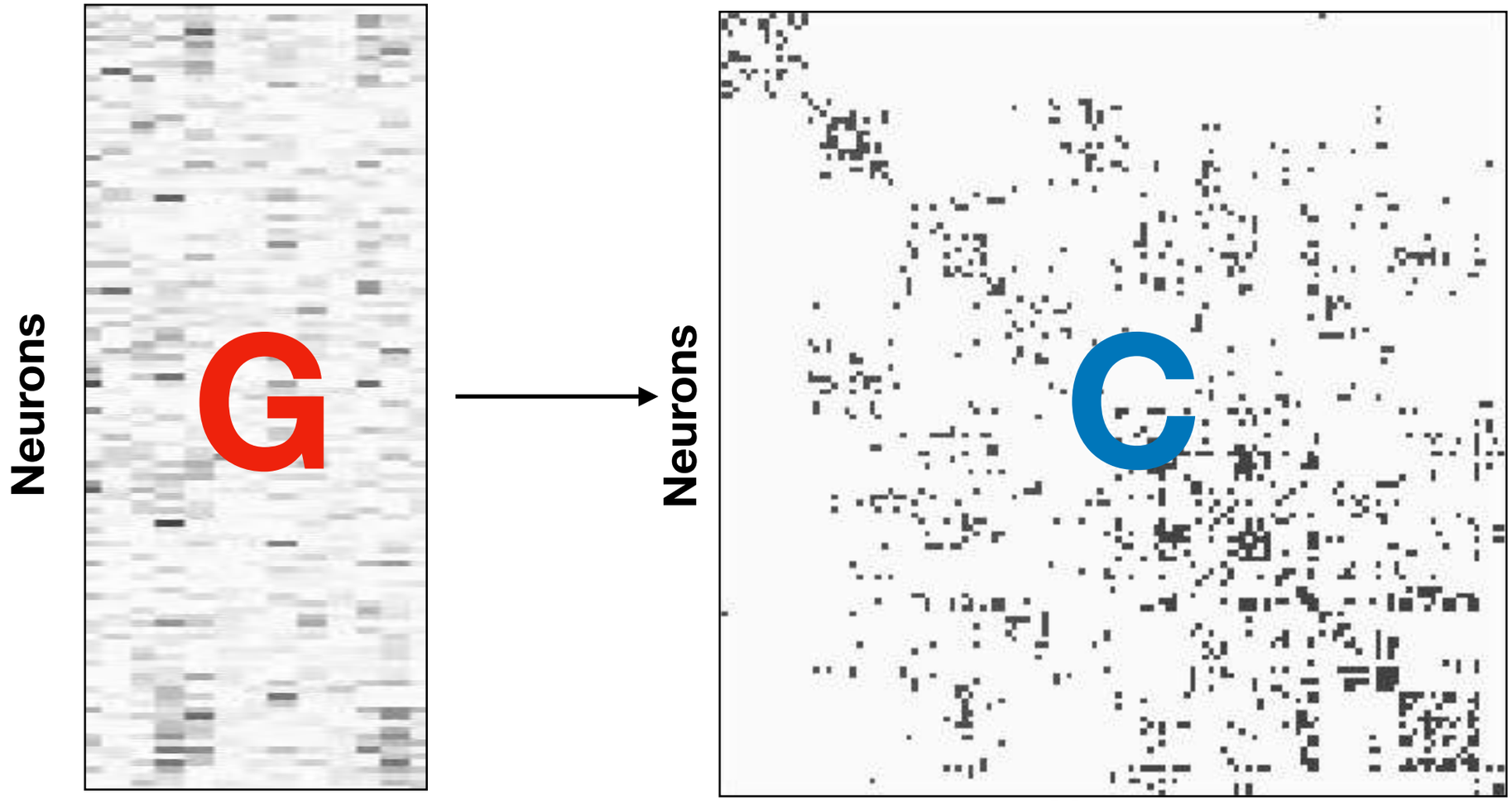

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Complete genome

Complete connectome

CeNGEN

Yemini,…,**Varol** et al. 2021 Cell

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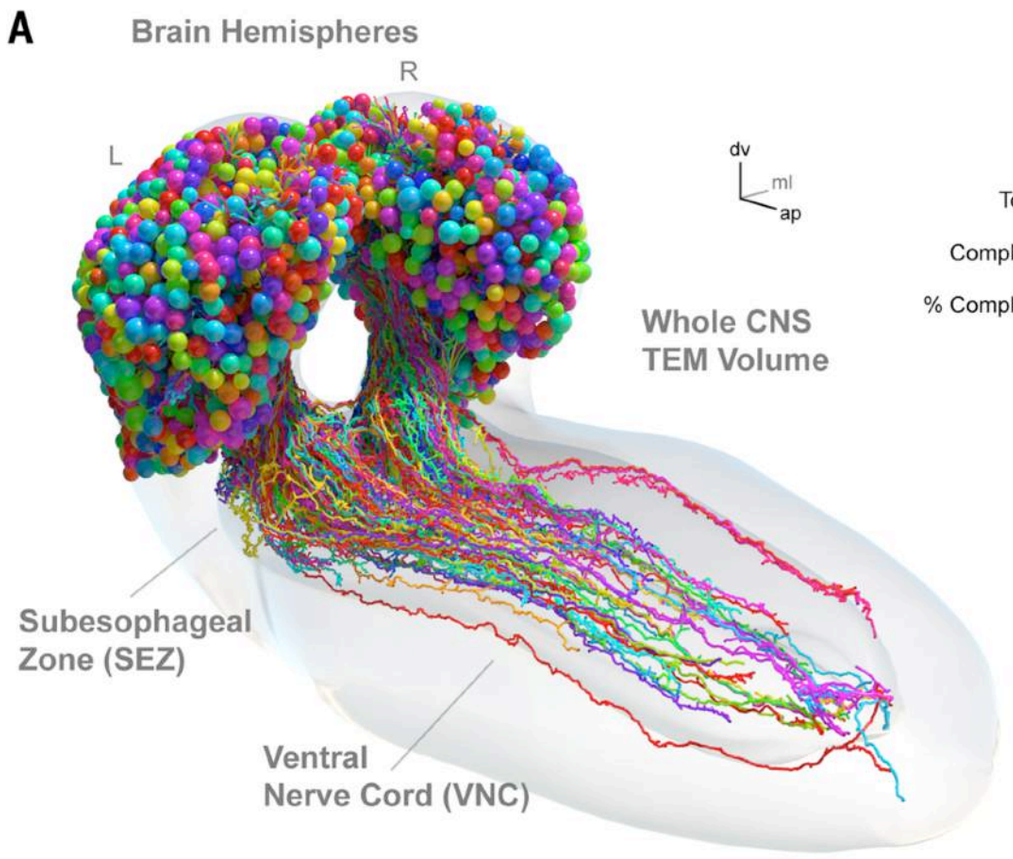
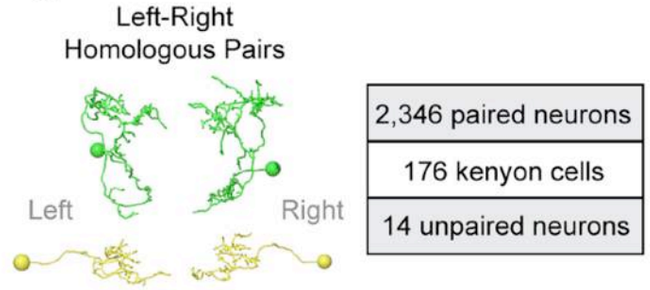
Reilly,…,**Varol** et al. 2020 nature

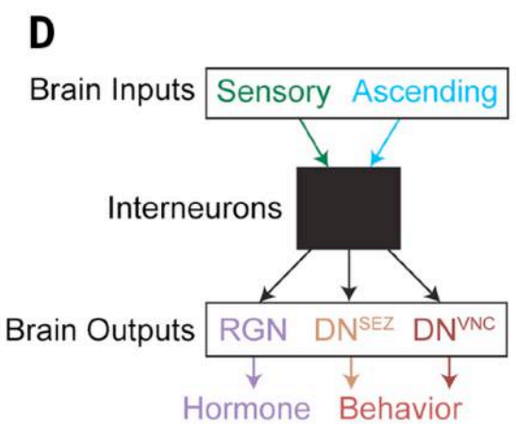
New challenges: Another fully mapped connectome *(D. melanogaster) - Can we decode its genetic blueprint?*

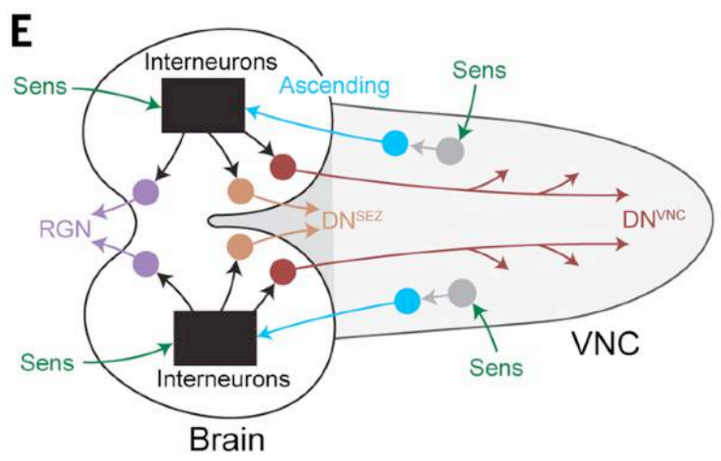


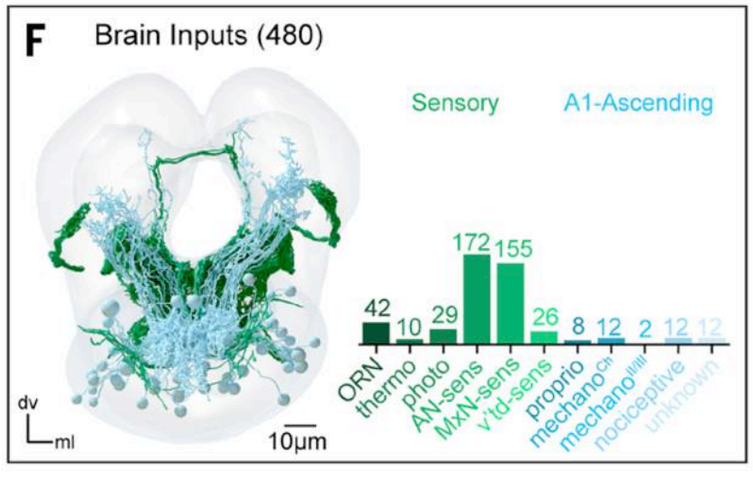
B

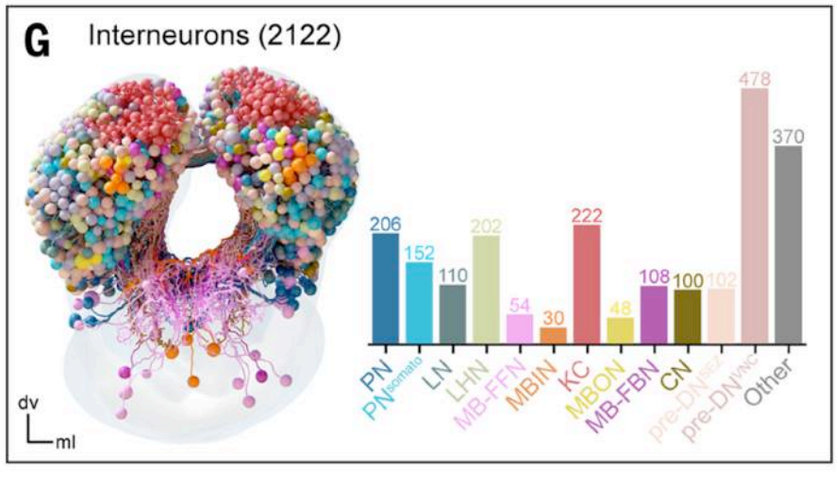
	Differentiated Neurons			Brain Synaptic Sites		
	Left	Right	All	Pre	Post	All
Total	1266	1270	2536	158k	575k	733k
Complete	1256	1259	2515	152K	396K	548K
% Complete	99.2%	99.1%	99.2%	96.2%	68.9%	74.8%

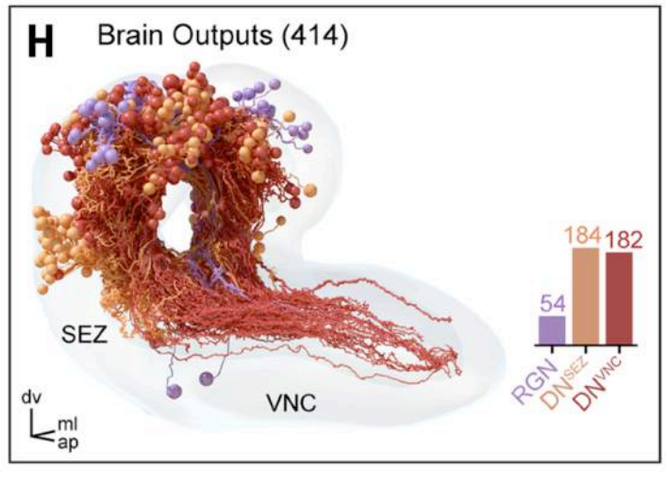






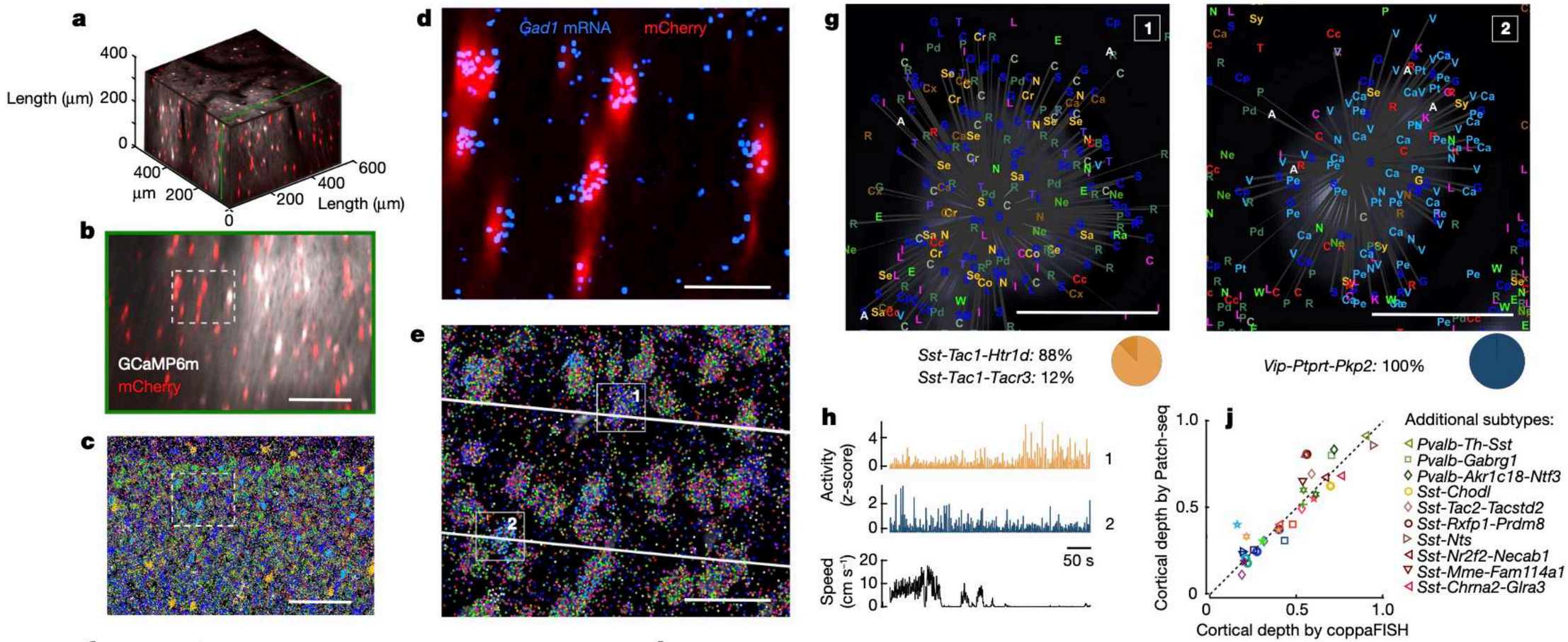






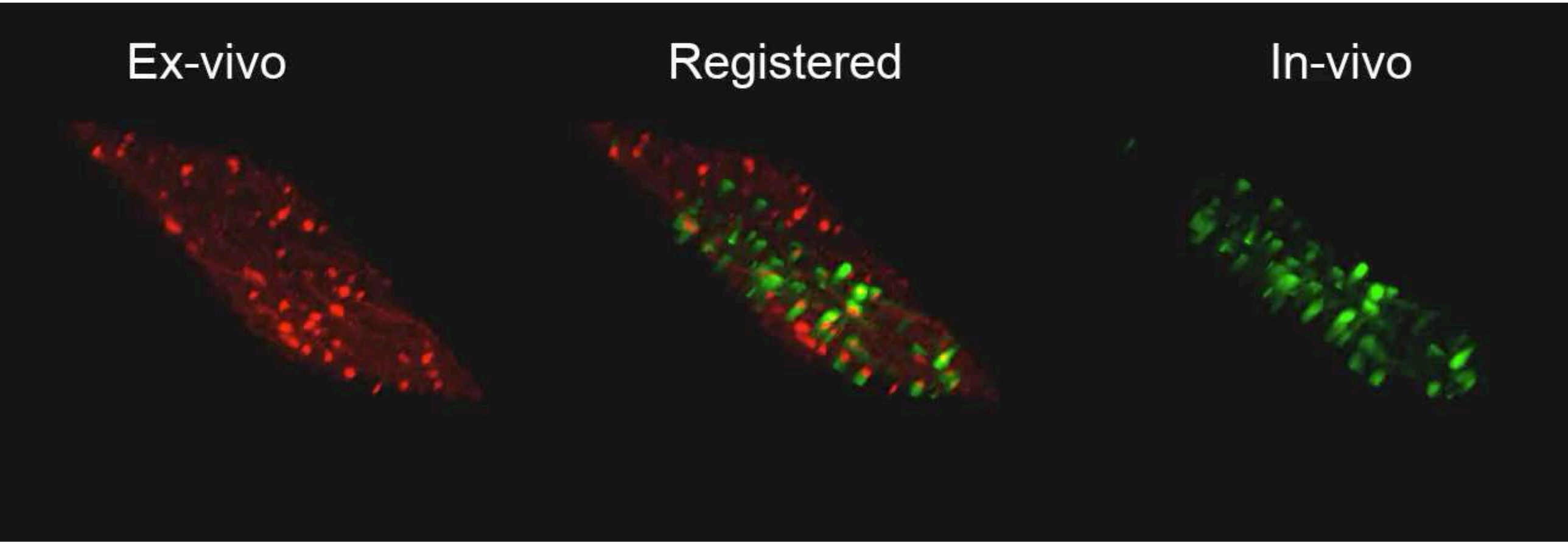
Winding et al. 2023 - Science

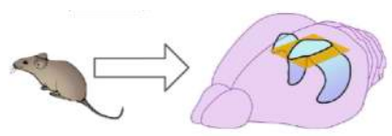
New challenges: Growing number of genes + number of neurons in spatial transcriptomics. Can we infer local connectivity/ proximity using gene expression? Can we infer functional correlation/connectivity from genetics?

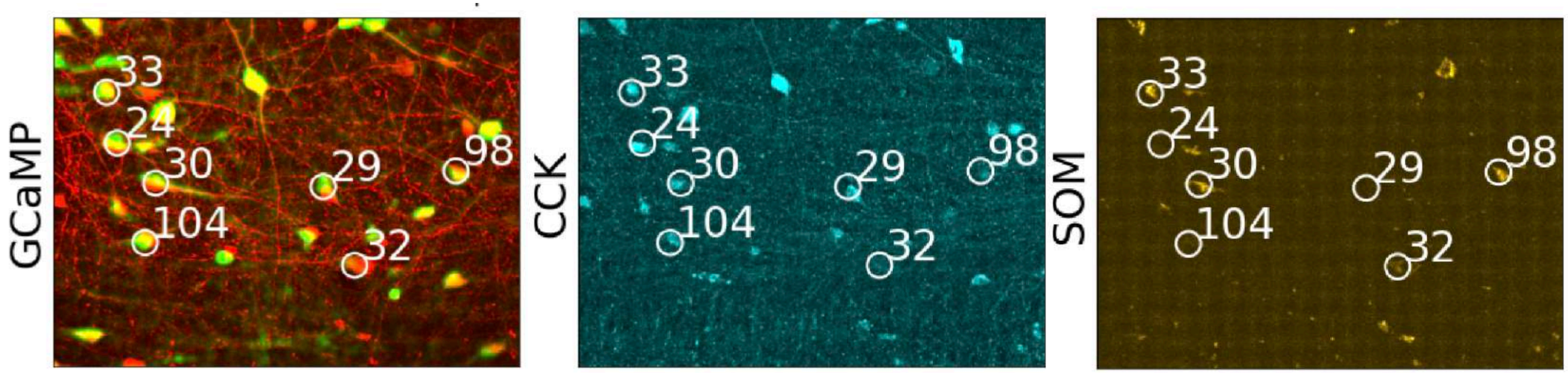


Bugeon et al. Nature 2022

We need to register connectomic data with genomic imaging:
New multi-modal registration technique to integrate functional calcium activity with gene expression in mouse hippocampus

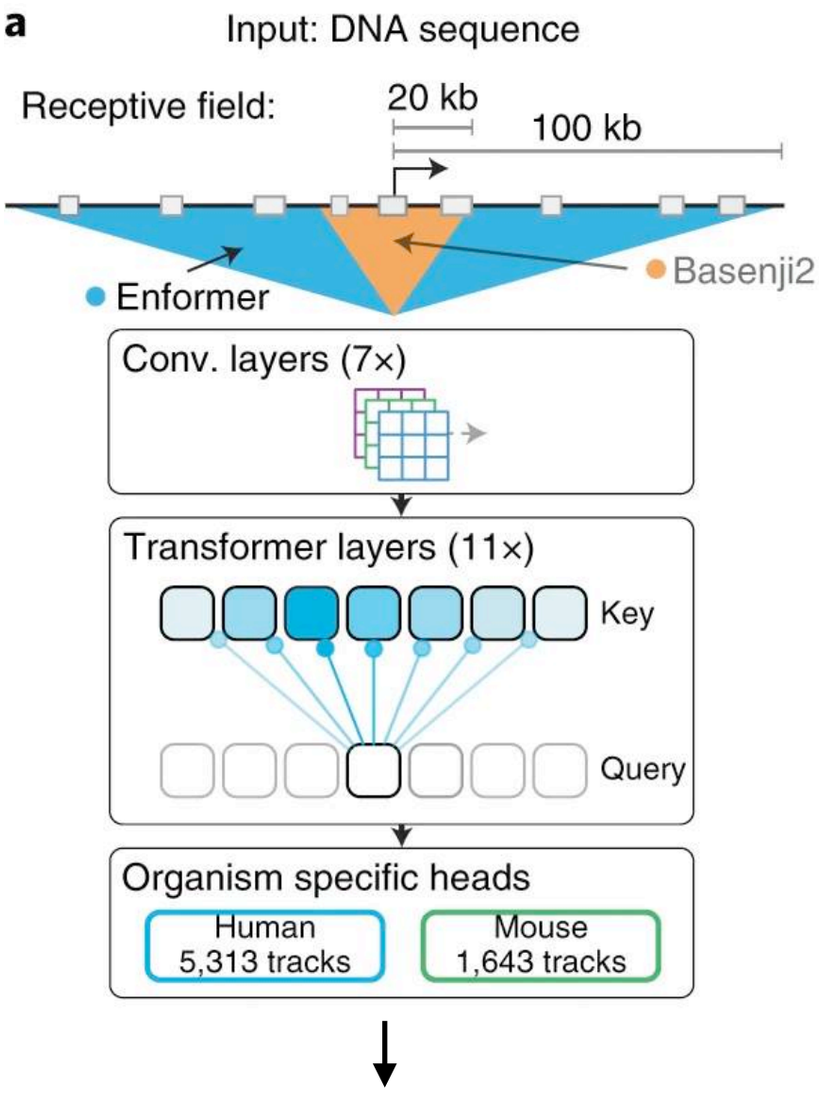






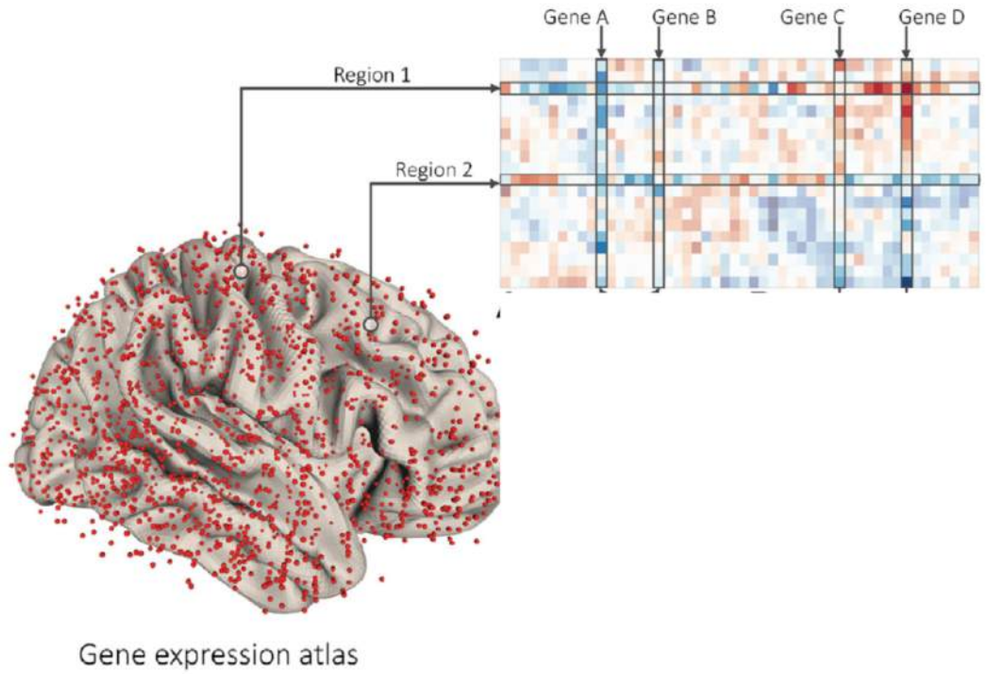
Chen,…,Paninski, **Varol** (ICASSP ’23)

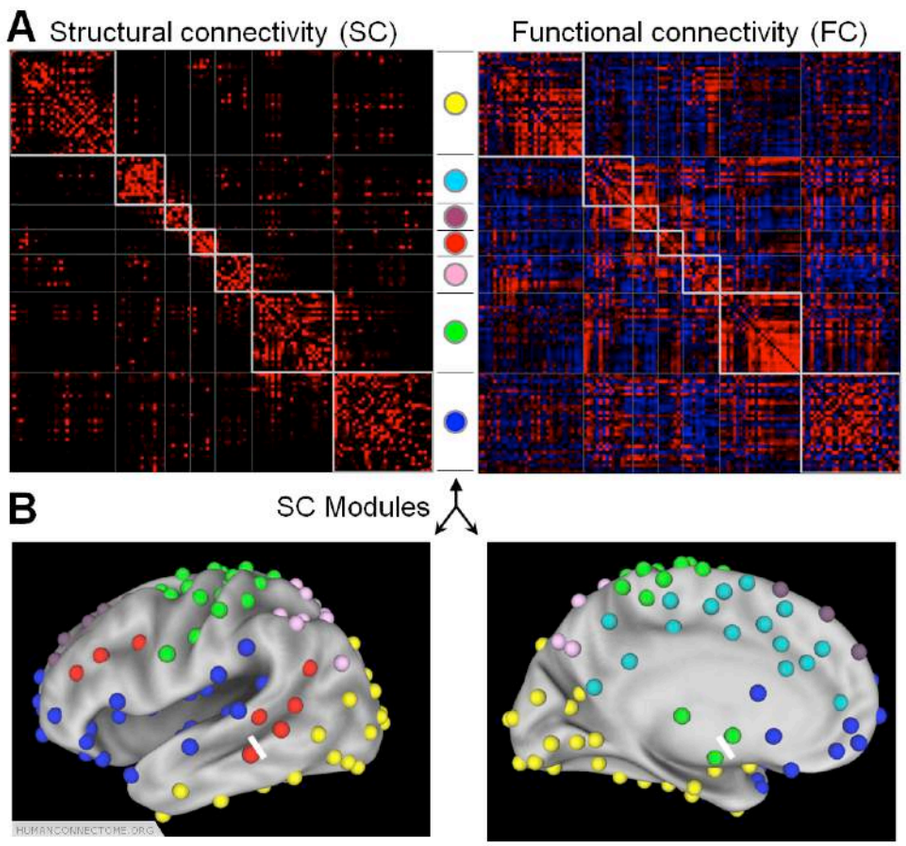
Can we read out connectivity from DNA sequence?



Output: Network connectivity

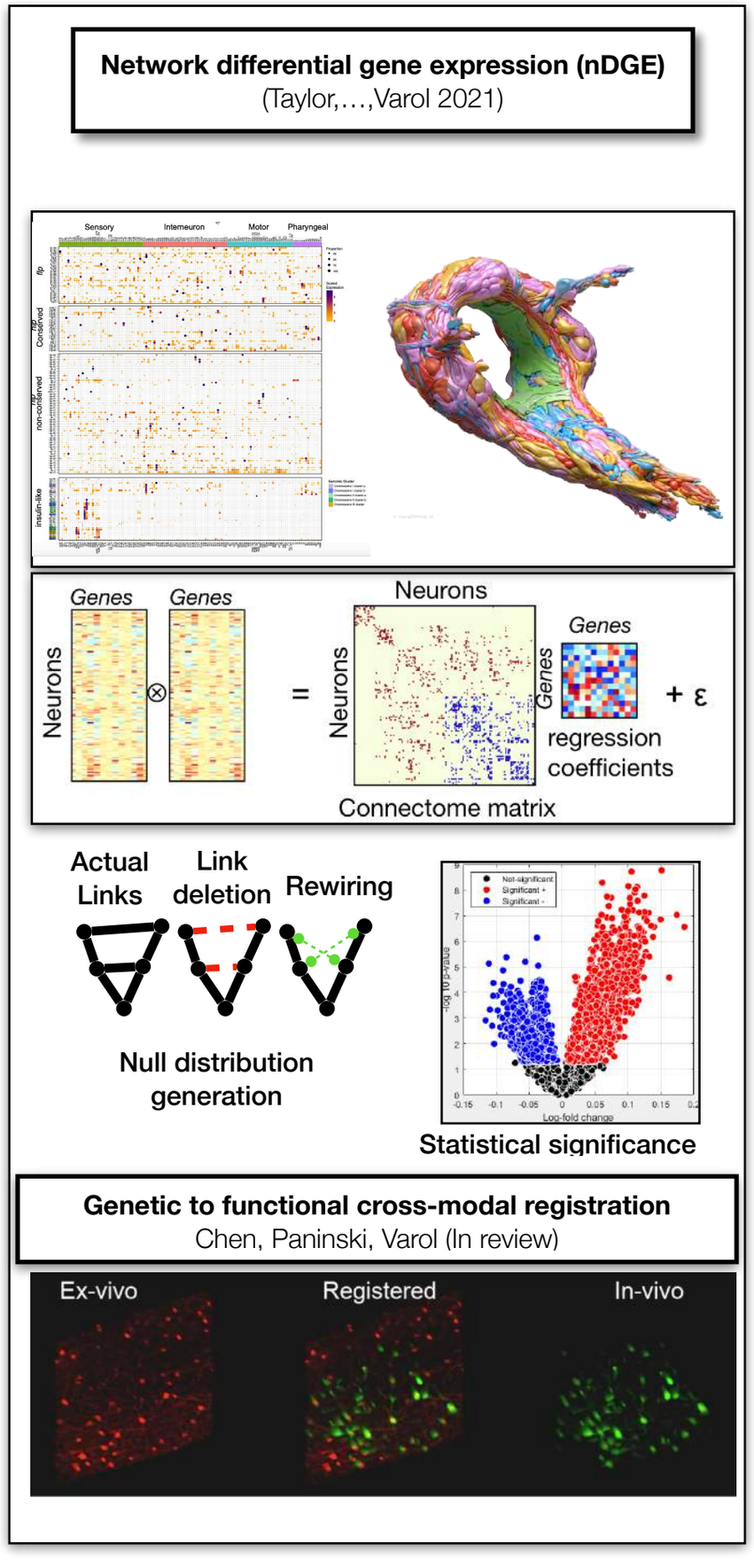
Datasets:
UKBiobank (>50K subjects),
HCP (>1K subjects),
ABCD (>12K subjects)





Contributions and **future work**

- **Integration** of connectomics with genomics
- **Tractable inference** with bilinear regression
- Biologically plausible **network sampling**
- Testable **genetic predictions**
- Novel **causal** genes discovered
- **Future work:**
  - functional connectomics
  - more complex brains (fruitfly - Claude Desplan @ NYU, mouse, human)



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Fellowships

FORD FOUNDATION PREDOCTORAL FELLOWSHIP PROGRAM

Deadline: December
Stipend support: $27,000 x 3 years

F31 Ruth L. Kirschstein Predoctoral Individual National Research Service Award

Deadline: December
Stipend support: $27,000 x 3 years

NDSEG National Defense Science and Engineering Graduate Fellowship Program

Deadline: October
Stipend support: $40,800 x 3 years

NSF Graduate Research Fellowship Program

Deadline: October
Stipend support: $37,000 x 3 years

the Hertz FOUNDATION

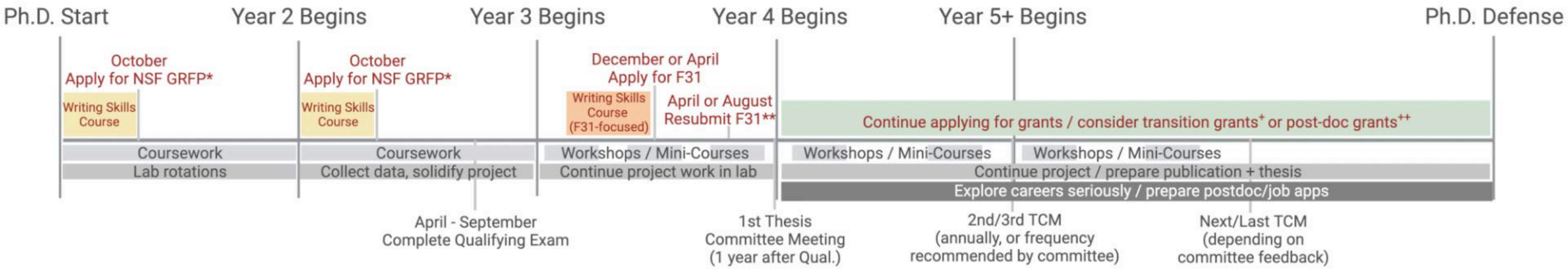
Deadline: October
Stipend support: $250K / 5 years

NIH Diversity Supplements

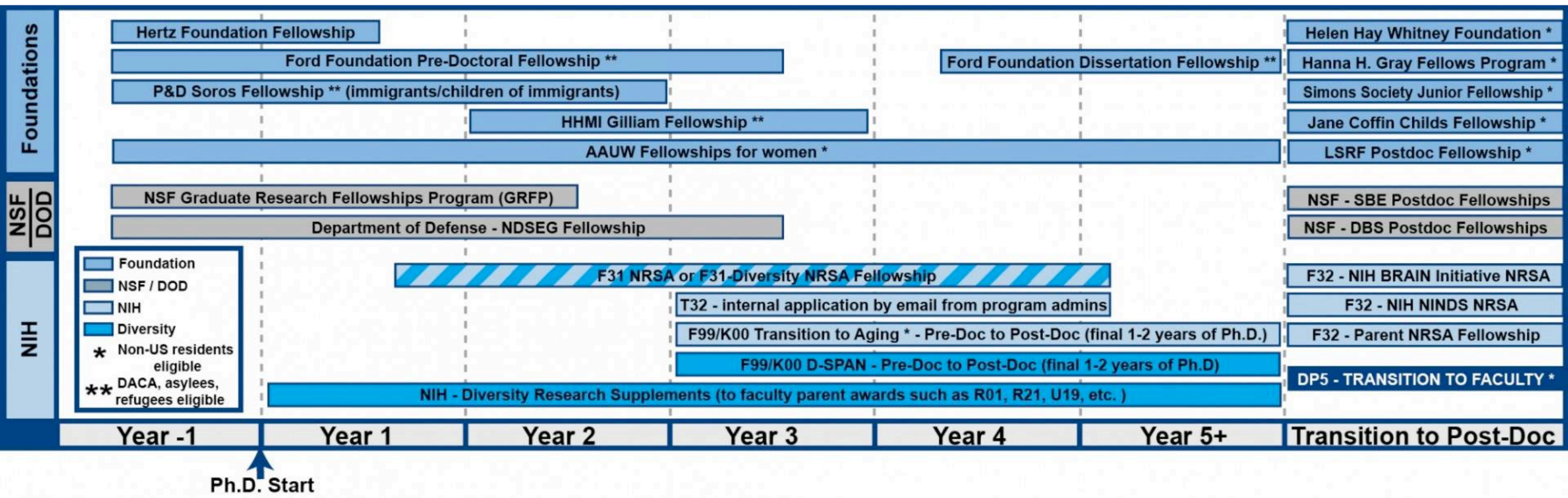
Deadline: October - December
Stipend support: $27,000 x 2 years

…and more

The Basics: Ph.D. Fellowships Timeline



* NSF GRFP: Can only apply for this grant once - choose either first or second year for your application.
** F31 resubmission: We recommend resubmitting or re-applying if yours isn't funded the first time. We've had students get it on their 3rd or 4th try, and even in their 5th year.
+ Transition grants: if eligible, F99/K00 awards fund the final 2 years of the Ph.D. + first 4 years of postdoc
++ Postdoc grants: up to 12 months before starting your postdoc, you are eligible to apply for many postdoc grants, but you must know your postdoc lab when you apply
Note: NSF GRFP and NIH F31 grants require U.S. citizenship or permanent residency. If you are not eligible for these, replace them with grants you are eligible for from resources on our website.



http://fellowship-opportunities.engineering.nyu.edu/graduate/

Menu

- PhD requirements
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- Available collaborations
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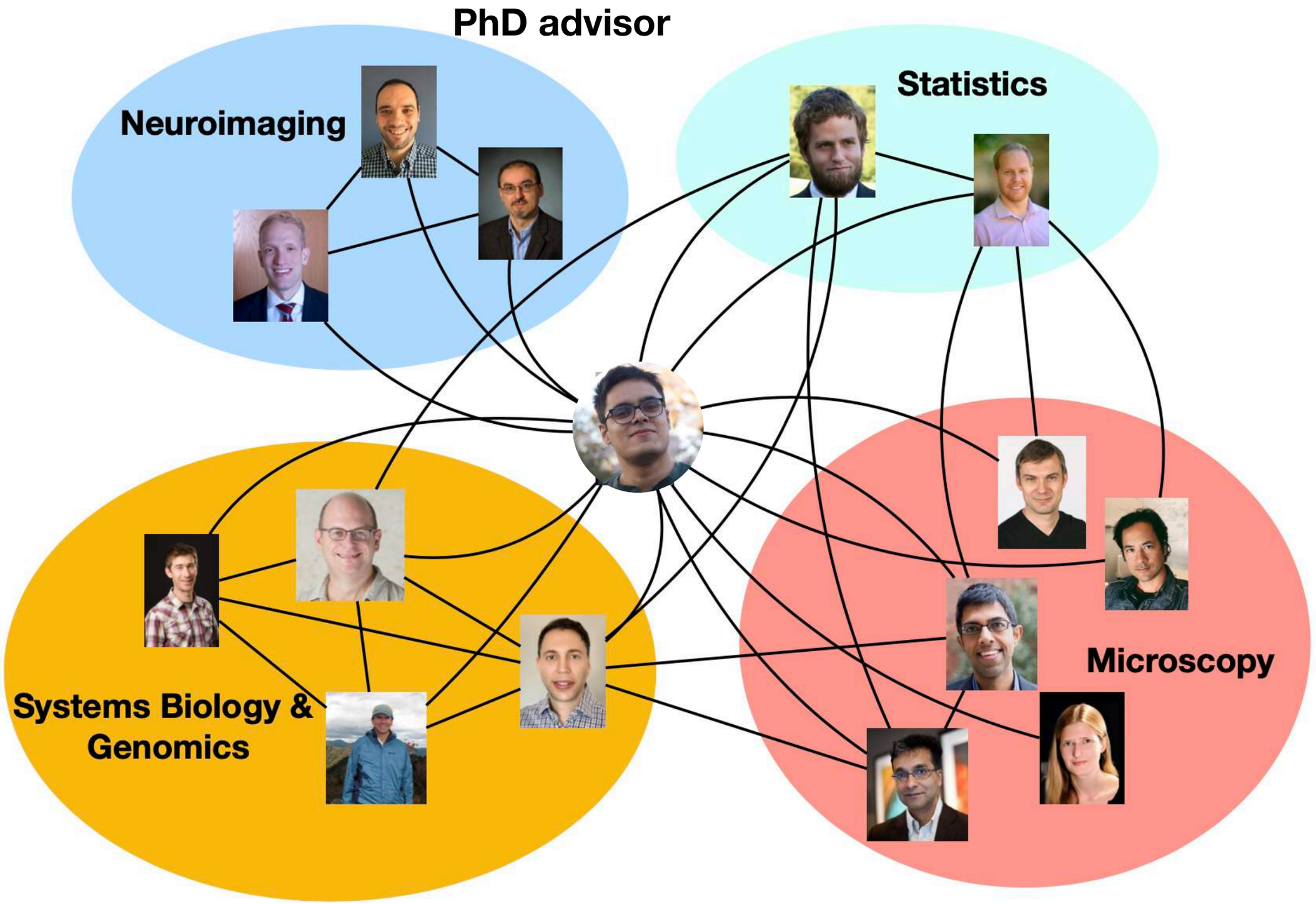
My “advisory” network when I was a grad-student/post-doc



Lab organization (in the perspective of a PhD student)

PI

Postdoc

Other PhD students

PhD Student

Advisory board

Collaborators

Lab schedule

Monday	Individual 1hr meetings with students / collaborators	Flexible timing
Tuesday	Individual 1hr meetings with students / collaborators	Flexible timing
Wednesday	Individual 1hr meetings with students / collaborators	Flexible timing
Thursday	Journal club	1 student presents a relevant paper to their research (rotated)
Friday	Lab meeting	1 student presents research updates (rotated)

After-hours / flexible mentoring support on Slack/Discord **neuroinfolab.slack.com**

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Diversity statement

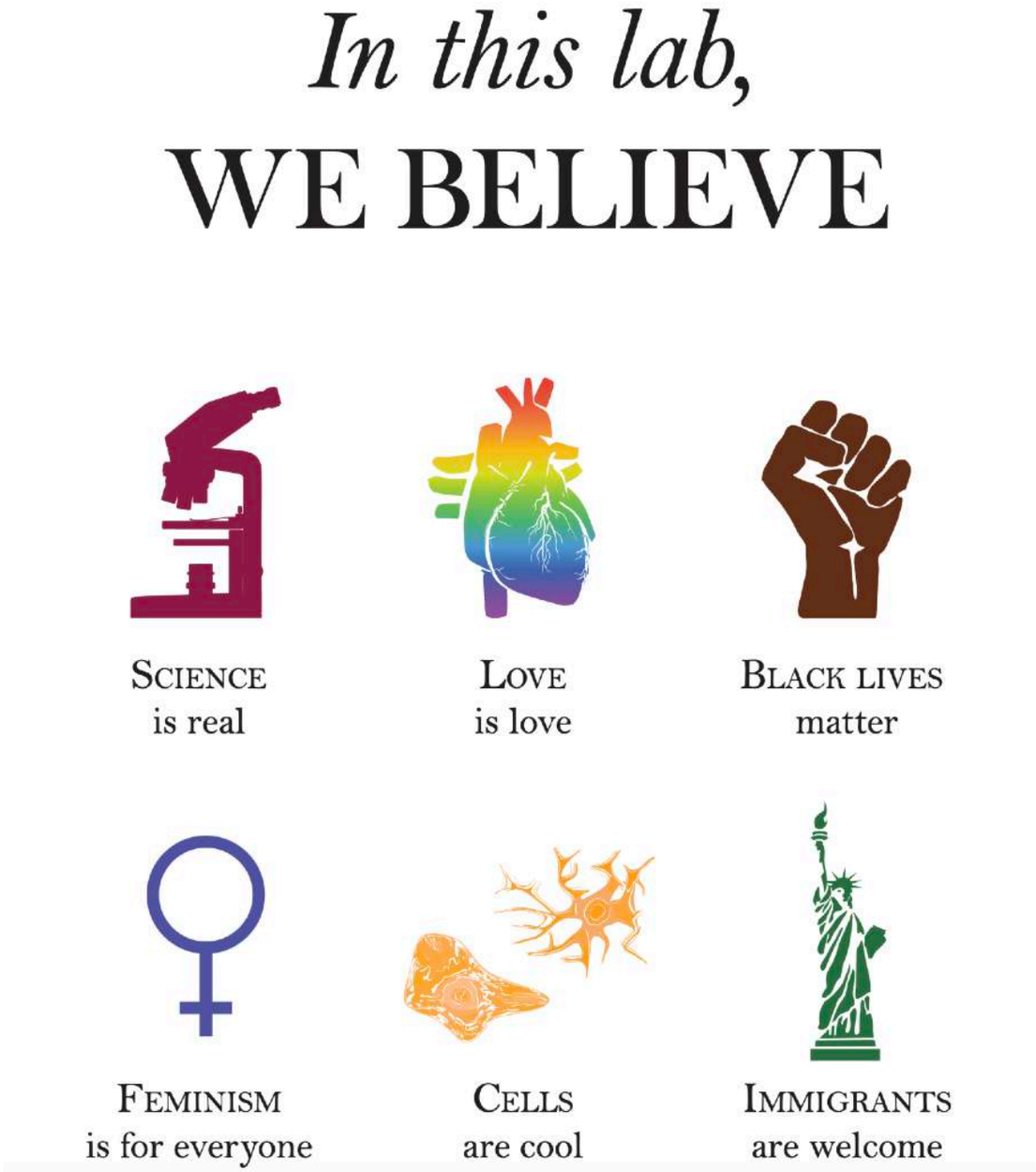
- We believe that better ideas emerge in science and engineering by a diverse ensemble of creators. We acknowledge that socioeconomic status, race, gender, and culture can be serious barriers of entry and we are committed to making an active effort to overcome these obstacles. Areas in which we aim to make impact are:

    - Hiring - have diverse lab demographics through hiring.

    - Outreach - encourage the next generation of scientists / engineerings through NYC high school mentoring programs (ARISE program)

    - Authorship - have equitable authorship lists.

    - Invited talks - we will invite underrepresented populations at the postdoc/faculty level to give talks at NYU and expand their network.



Artwork by Sammy Katta

Signed: E. Varol (Spring '23)

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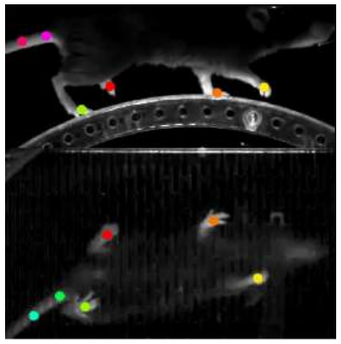
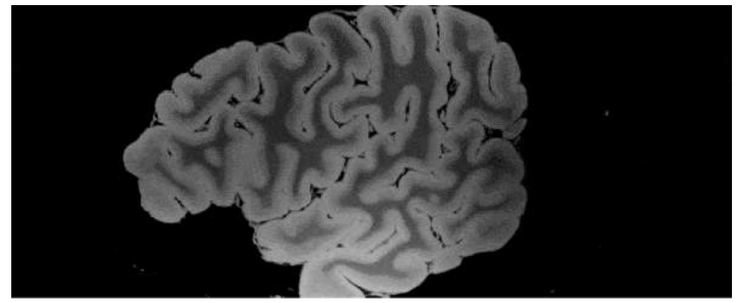
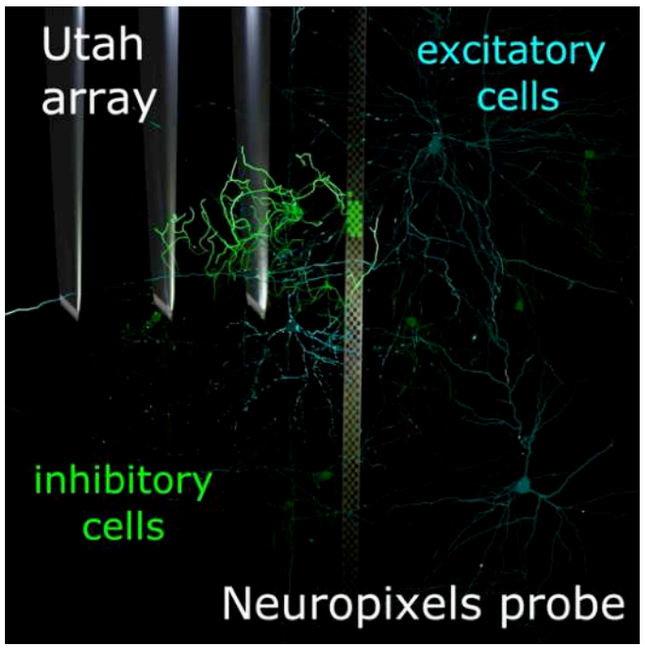
Collaborators



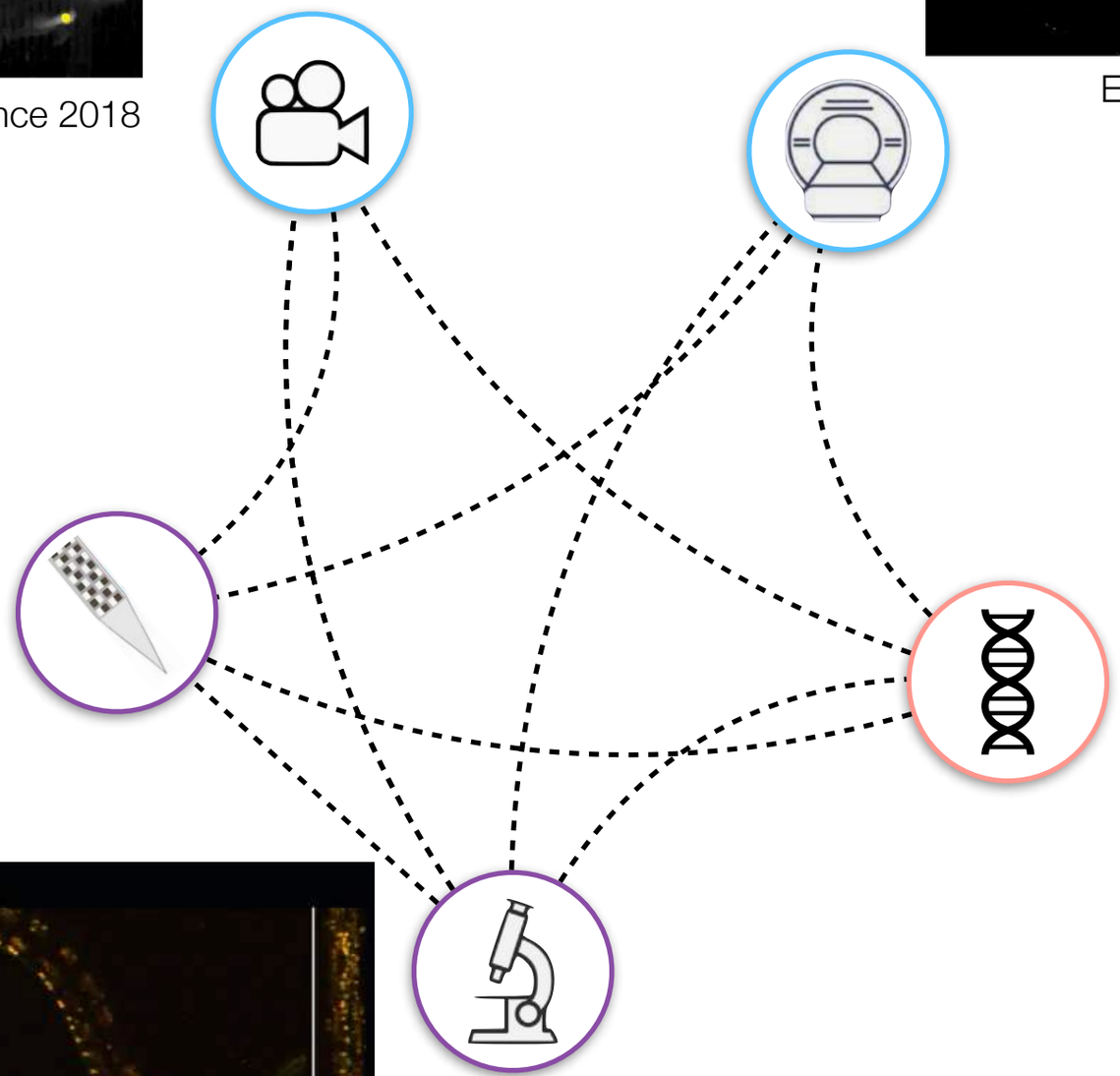
Mathis et al. Nature Neuroscience 2018

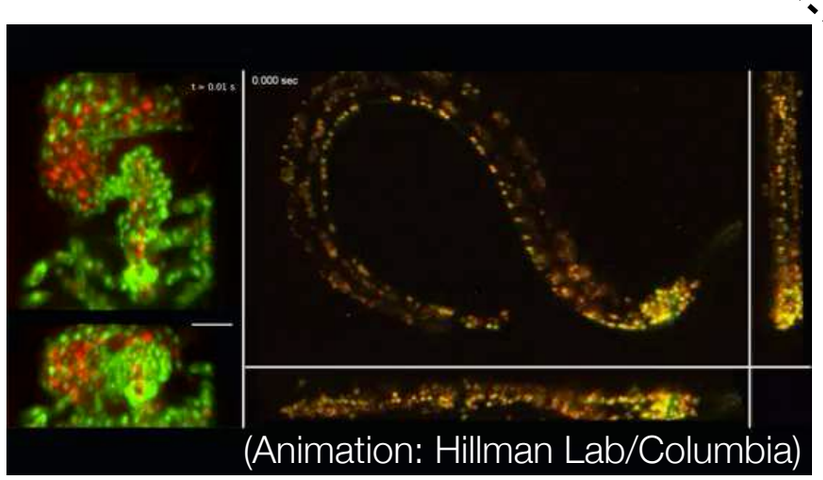


Edlow et al. Scientific Data 2019

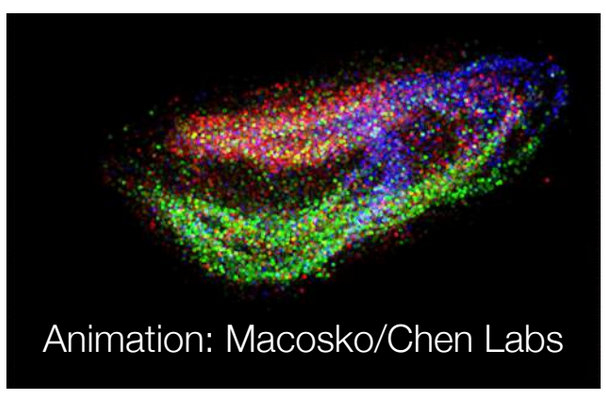


(Animation: Angelique Paulk/MGH)



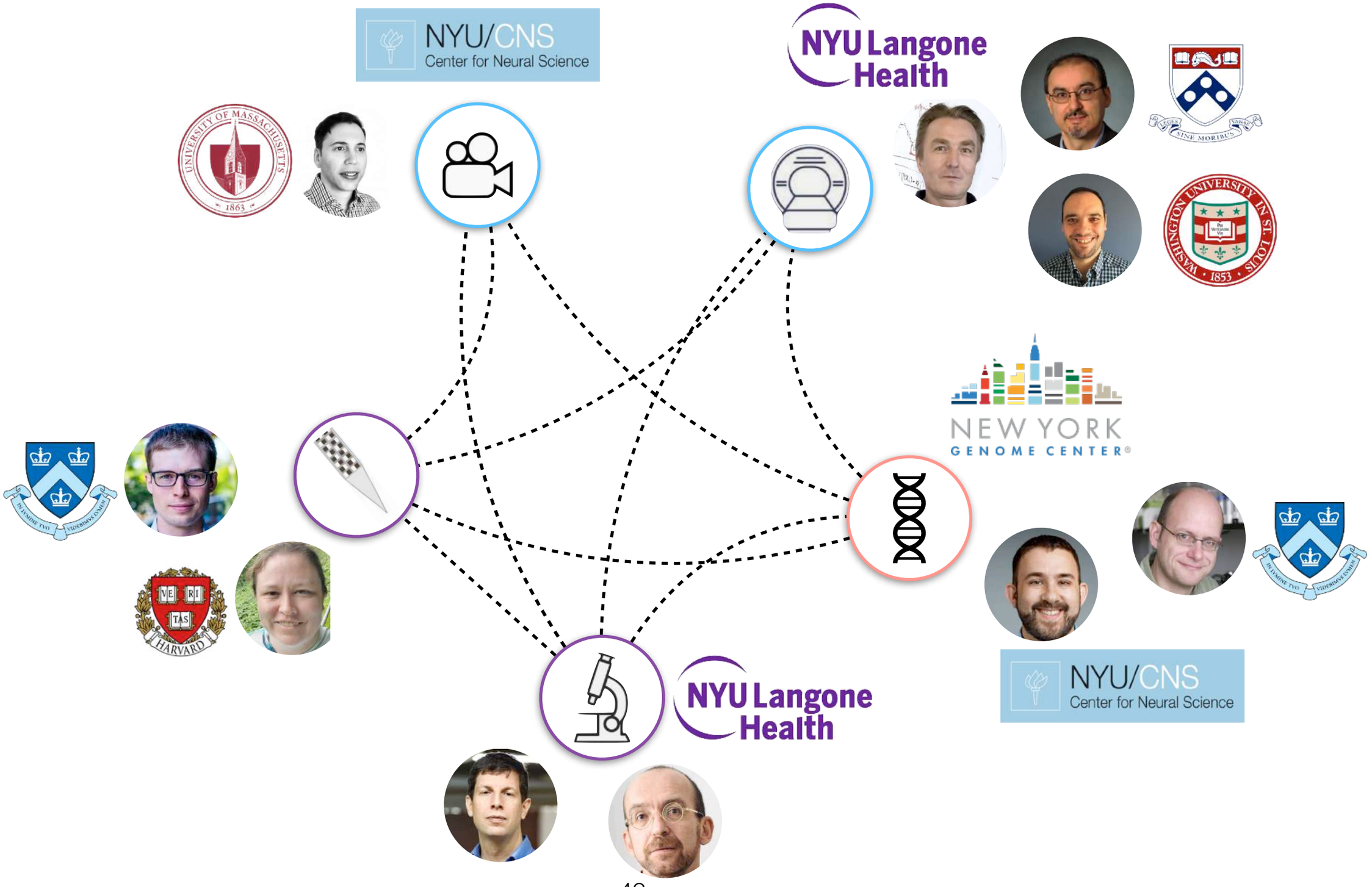


(Animation: Hillman Lab/Columbia)



Animation: Macosko/Chen Labs

Local and non-local collaborators



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Expectations

- State intention to submit fellowship applications before September ’23 so we can plan accordingly. Especially encouraged for students who want to pursue post-doc/faculty positions later.
- “Rotation” through 1-2 projects in the first year before choosing thesis direction
    - By the end of “rotations”, student is expected to either
        - 1. Select a thesis direction from the existing project directions
        - 2. Propose a new one with some supporting data
            - This is to facillitate setting up the necessary advisory board / collaborators for student by the start of 2nd year.
- 3 research projects for thesis
    - Each project = At least 1 conference paper or 1 journal paper (as deemed appropriate). Can be more.
- 1st research project pre-print by end of 2nd year (this is part of the depth requirement)
- Show up to lab meeting (please)
- Contribute to revising this document at the end of each year (especially diversity)

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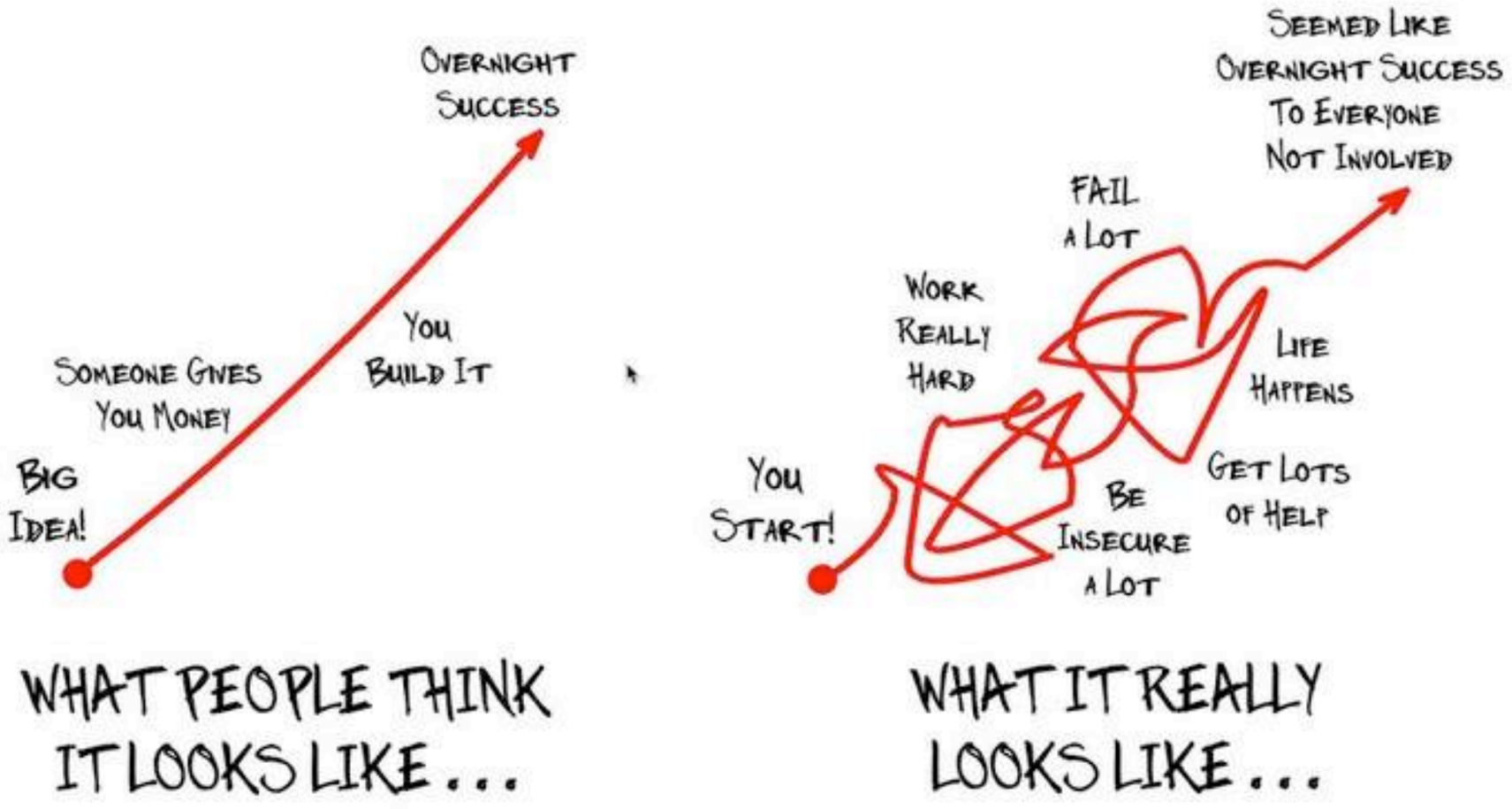
Typical timeline

Year 1	Year 2	Year 3	Year 4	Year 5
Take courses	Take courses	Take courses (optional)	Take courses (optional)	Take courses (optional)
Apply to fellowships			Apply to pre/ post-doctoral transition awards	Apply to pre/ post-doctoral transition awards
		Apply to internships	Apply to internships	
Start project 1		Start project 2		Start project 3
	Submit paper 1		Submit paper 2	Submit paper 3
	Travel to conferences	Travel to conferences	Travel to conferences	Travel to conferences
	Qual		Thesis proposal	Thesis defense

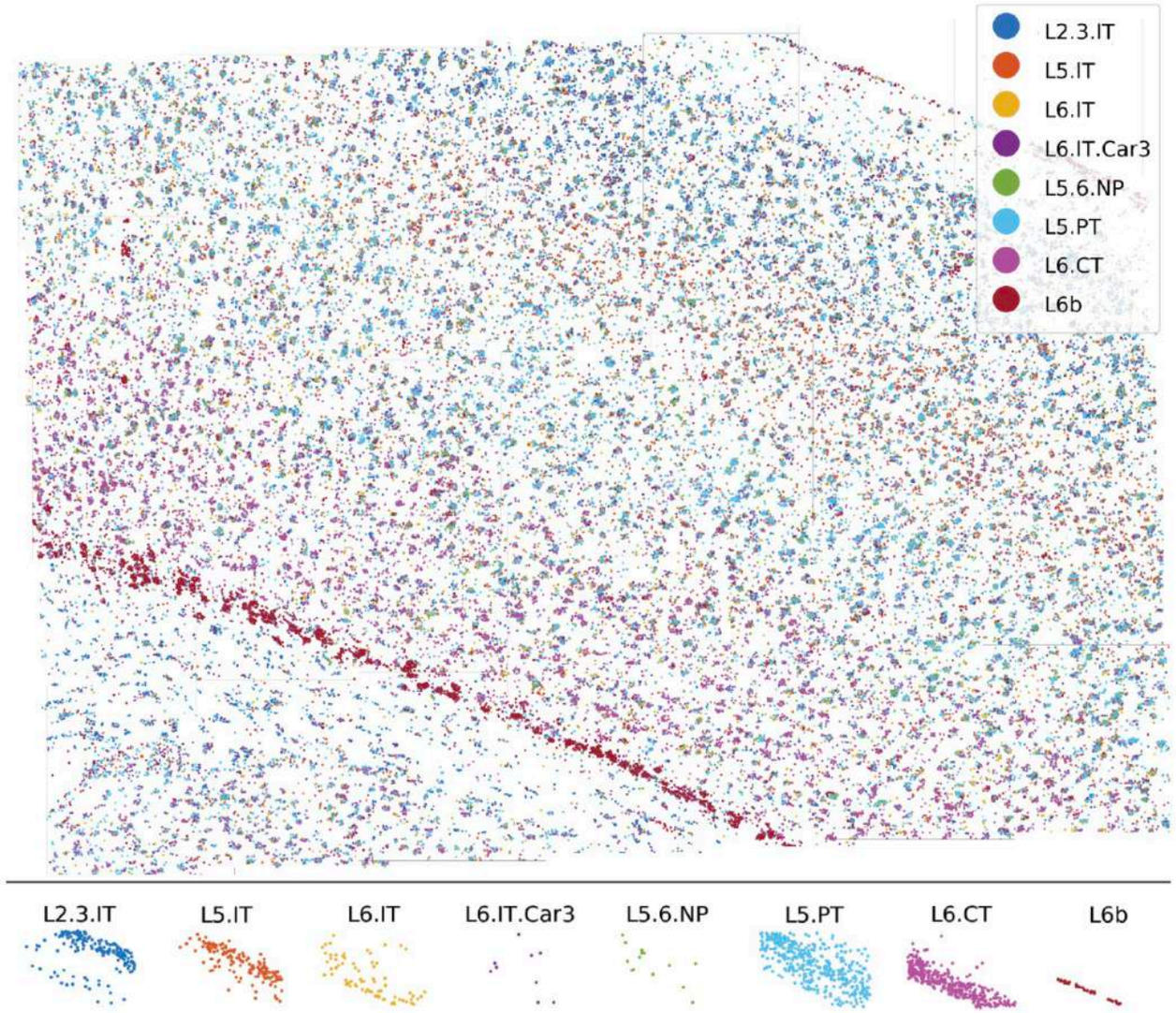
Example of Phd progression



Shuonan

Actual example

- **Starting point (2019):** interest in spatia genomics, thesis idea: not clear yet
- **First project (2021):** Counting gene spots in spatial genomics data
- **Second project (2022):** Segmenting ce shapes from spatial genomics
- **Third project (2023):** Matching spatial genomics with functional imaging
    - Thesis idea emerges: Tying function to genomics
- **Fourth project (~2024):** Building a network model of mouse brains using genetics
    - Thesis: Genetic blueprint of the mouse hippocampus



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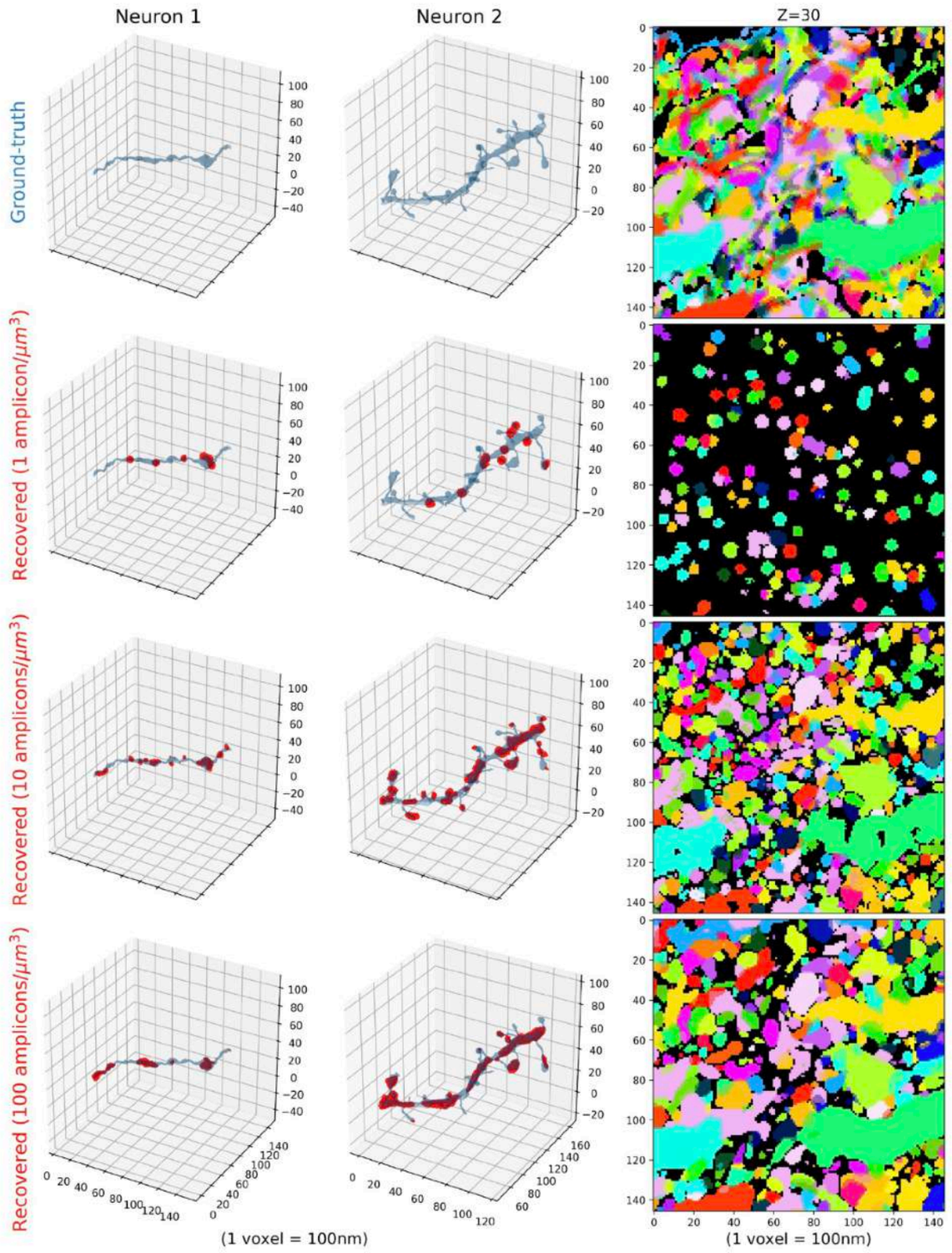

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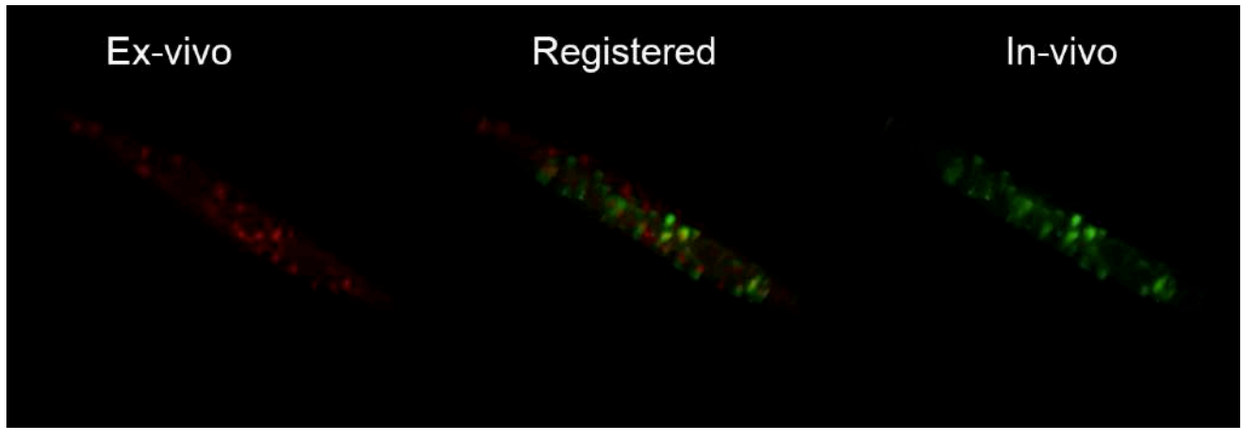

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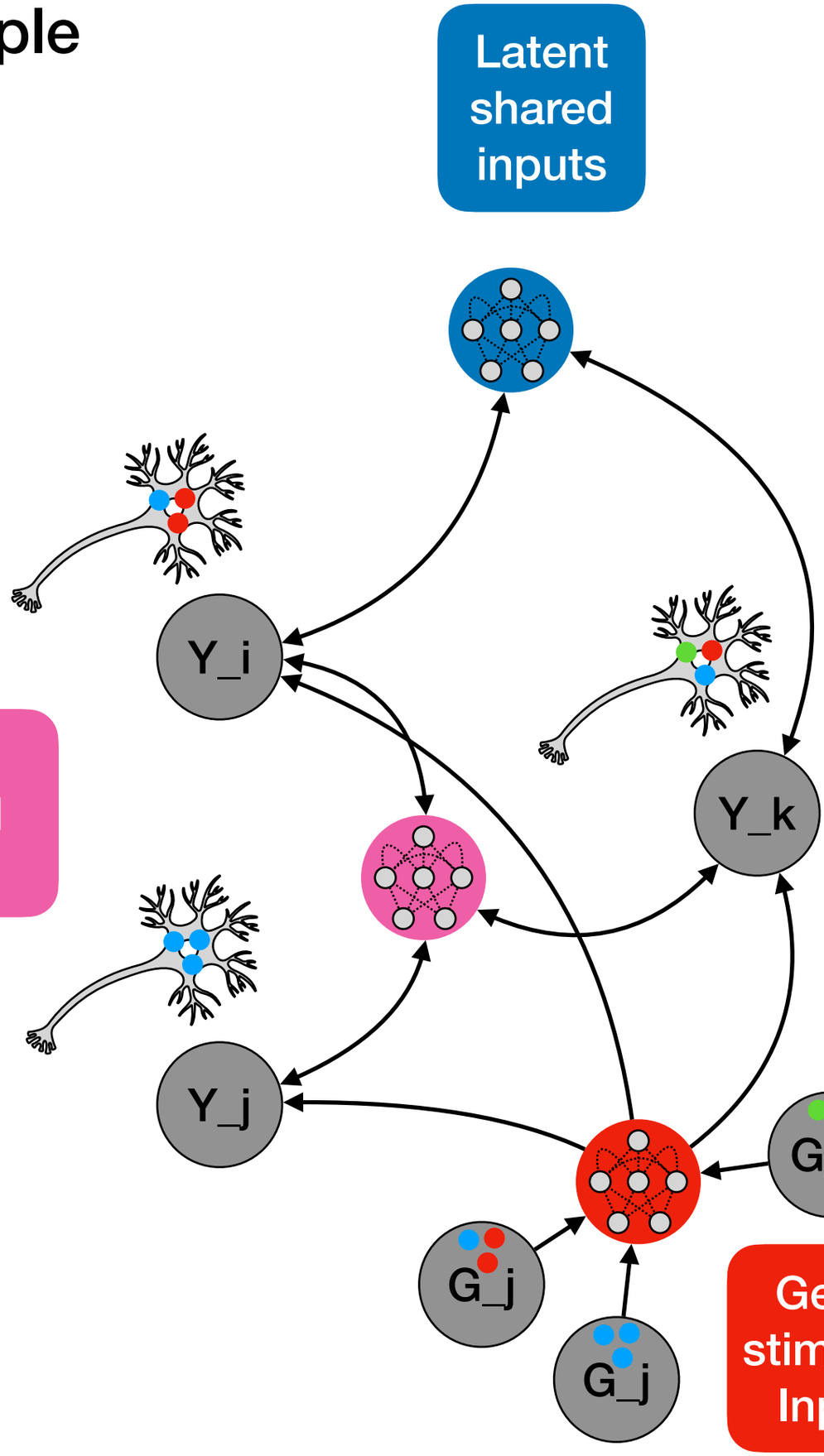
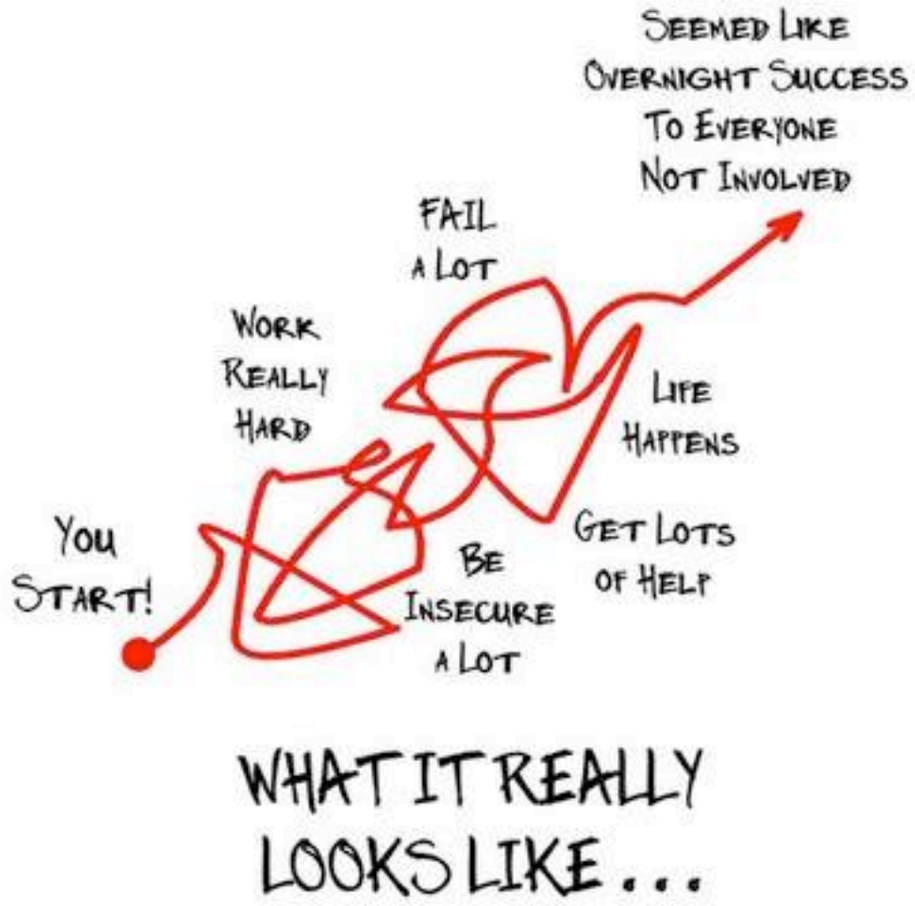
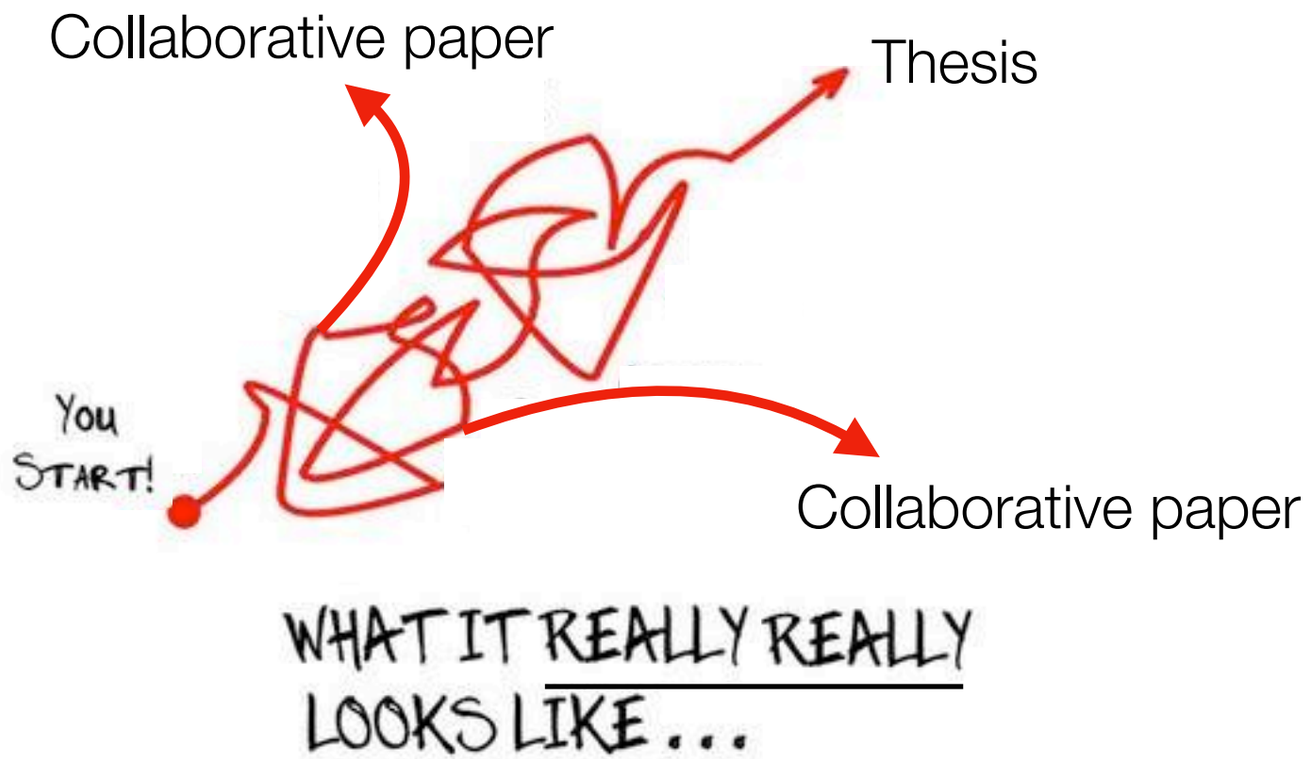


The path also isn't a "path" but a tree





Amin

Actual example

Amin Nejatbakhsh

Flatiron Research Fellow, Flatiron Institute
Verified email at flatironinstitute.org - Homepage

Machine Learning Statistics Dynamical Systems Optimization Neuroscience

FOLLOW

TITLE	CITED BY	YEAR
Toward a more accurate 3D atlas of C. elegans neurons M Skuhersky, T Wu, E Yemini, A Nejatbakhsh, E Boyden, M Tegmark BMC bioinformatics 23 (1), 1-18	1	2022
Scalable Tools for Information Extraction and Causal Modeling of Neural Data A Nejatbakhsh Columbia University		2022
Versatile Multiple Object Tracking in Sparse 2D/3D Videos Via Diffeomorphic Image Registration J Yu, A Nejatbakhsh, M Torkashvand, S Gangadharan, ... bioRxiv, 2022.07. 18.500485	1	2022
Estimating the unique information of continuous variables A Pakman, A Nejatbakhsh, D Gilboa, A Makkeh, L Mazzucato, M Wibral, ... Advances in neural information processing systems 34, 20295-20307	11 *	2021
Visualizing the organization and differentiation of the male-specific nervous system of *C. elegans* T Tekieli, E Yemini, A Nejatbakhsh, C Wang, E Varol, RW Fernandez, ... Development 148 (18), dev199687	8	2021
NeuroPAL: a multicolor atlas for whole-brain neuronal identification in C. elegans E Yemini, A Lin, A Nejatbakhsh, E Varol, R Sun, GE Mena, ADT Samuel, ... Cell 184 (1), 272-288. e11	138 *	2021
Neuron Matching in C. elegans With Robust Approximate Linear Regression Without Correspondence A Nejatbakhsh, E Varol Proceedings of the IEEE/CVF Winter Conference on Applications of Computer ...	11 *	2021
Predicting perturbation effects from resting activity using functional causal flow A Nejatbakhsh, F Fumarola, S Esteki, T Toyoizumi, R Kiani, L Mazzucato bioRxiv, 2020.11. 23.394916	1	2020
Extracting neural signals from semi-immobilized animals with deformable non-negative matrix factorization A Nejatbakhsh, E Varol, E Yemini, V Venkatachalam, A Lin, ADT Samuel, ... bioRxiv, 2020.07. 07.192120	9 *	2020
Sinkhorn em: an expectation-maximization algorithm based on entropic optimal transport G Mena, A Nejatbakhsh, E Varol, J Niles-Weed arXiv preprint arXiv:2006.16548	6	2020
Sinkhorn permutation variational marginal inference G Mena, E Varol, A Nejatbakhsh, E Yemini, L Paninski Symposium on Advances in Approximate Bayesian Inference, 1-9	3	2020
Statistical Atlas of *C. elegans* Neurons E Varol, A Nejatbakhsh, R Sun, G Mena, E Yemini, O Hobert, L Paninski Medical Image Computing and Computer Assisted Intervention–MICCAI 2020: 23rd ...	8	2020
Probabilistic Joint Segmentation and Labeling of *C. elegans* Neurons A Nejatbakhsh, E Varol, E Yemini, O Hobert, L Paninski Medical Image Computing and Computer Assisted Intervention–MICCAI 2020: 23rd ...	5	2020
Temporal Wasserstein non-negative matrix factorization for non-rigid motion segmentation and spatiotemporal deconvolution E Varol, A Nejatbakhsh, C McGrory arXiv preprint arXiv:1912.03463	3	2019

Thesis →

Thesis chapter →

Thesis chapter →

Thesis chapter →

← **Development paper**

← **Cell paper**