BRIEFING 12 · BRAIN & NEUROTECH

Princeton's 3D maps of the mind: FlyWire and MICrONS

A deep dive into connectomics: how Princeton-led teams mapped every neuron in a fruit fly brain and a cubic millimeter of mouse cortex in 3D, how AI and gamers made it possible, and what wiring diagrams mean for medicine and AI.

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Edition of 2026-11-22

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A deep dive into connectomics: how Princeton-led teams mapped every neuron in a fruit fly brain and a cubic millimeter of mouse cortex in 3D, how AI and gamers made it possible, and what wiring diagrams mean for medicine and AI.

139,255	54.5 million	524 million	1.6 PB
neurons in the fly connectome	fly synapses	synapses in 1 mm^3 of mouse cortex	MICrONS data release

Key takeaways

- A connectome is a complete 3D wiring diagram of a nervous system: every neuron and every connection.
- FlyWire (Nature, October 2024), led by Princeton, mapped all 139,255 neurons and about 54.5 million synapses of an adult fruit fly brain.
- MICrONS (April 2025), co-led by Princeton, Baylor and the Allen Institute, mapped one cubic millimeter of mouse visual cortex: over 524 million synapses and 200,000+ cells, plus recordings of the same neurons' activity.
- AI did most of the tracing; humans, including volunteer gamers, proofread, a model of human–AI collaboration at scale.
- Connectomes are reference maps, like the genome, for understanding brain function, disease and more efficient AI.

A short history

- **1986:** the 302-neuron connectome of the worm *C. elegans* was published after years of manual tracing.
- **2012:** Sebastian Seung's book *Connectome* argued "you are your connectome", and his lab launched Eyewire, a game where volunteers trace neurons.
- **2020:** the "hemibrain" mapped about 25,000 neurons in part of a fly brain [3].
- **2024:** FlyWire completed the whole adult fly brain [3][6].
- **2025:** MICrONS released the largest mammalian wiring diagram with matching activity data [1][4].

How a connectome is made

1. **Prepare and slice:** a small piece of brain is stained and cut into thousands of ultra-thin sections, or milled layer by layer.
2. **Image:** electron microscopes capture each slice at nanometer resolution, producing petabytes of images.
3. **Align:** software stitches slices into a 3D volume.
4. **Segment:** convolutional neural networks trace every neuron and detect synapses.
5. **Proofread:** scientists and volunteers fix merge and split errors.

6. **Analyze:** the graph of neurons and synapses is studied like a network.

FlyWire: the whole fly brain

- Published in Nature on 2 October 2024 as a package of papers led by Princeton with partners including Cambridge [2][3].
- Covers 139,255 neurons and about 54.5 million chemical synapses in an adult female fruit fly [3][6].
- Proofreading took an estimated 33 person-years from the FlyWire Consortium; Seung said that without AI the project would have needed almost 50,000 person-years [2][3].
- Data is openly explorable online through the FlyWire Codex [6].

MICrONS: a cubic millimeter of mouse cortex

- One cubic millimeter of mouse visual cortex reconstructed, with more than 524 million synapses, over 200,000 cells and about 4 km of axons [4][5].
- Before slicing, the team recorded how neurons responded to what the mouse saw, so structure and function are linked [5].
- A 1.6-petabyte release published in Nature and Nature Methods on 9 April 2025, co-led by Princeton, Baylor College of Medicine and the Allen Institute [1][4][5].

How it could change life

- **Medicine:** comparing healthy and disease-model circuits can reveal what goes wrong in epilepsy, autism or neurodegeneration.
- **Neuroscience:** testing theories of how circuits compute against real wiring.
- **AI:** real connectivity patterns inspire more efficient neural network architectures.
- **Neurotech:** ground truth for brain-computer interfaces and organoid computing.

Future scenarios

2027–2028	2030	2035	2040+
Larger mouse-brain regions; disease-model comparisons.	Whole-mouse-brain connectome efforts become feasible as AI tracing improves.	Detailed maps of human brain regions linked to function and disease.	Connectome-constrained brain simulations used in research and drug discovery.

- **Optimistic:** a whole-mouse-brain connectome by the early 2030s transforms neuroscience.
- **Base case:** steadily larger regional maps with linked activity data.
- **Pessimistic:** exabyte-scale storage and proofreading costs slow progress.

Effects and risks

- **Data scale:** a whole mouse brain would be exabytes; storage, compute and analysis become core challenges.
- **Interpretation:** a wiring diagram isn't an explanation; activity, chemistry and models are also needed.
- **Ethics:** human connectomics raises questions about privacy, identity and consent.

What to watch

- Whole-mouse-brain connectome milestones.
- Automated proofreading that reduces human effort.
- Studies linking connectome differences to disease.

Connection to my work

Connectomics is one of science's great data-infrastructure feats: petabyte pipelines, GPU-heavy segmentation, global collaboration tools and open data portals. Reliability, cost and observability at that scale are exactly the problems I work on, and they will define how fast neuroscience can go next.

My take

FlyWire and MICrONS show what happens when AI pipelines and human judgment work together at scale. They're also a reminder that the hardest part of big science is often the infrastructure underneath it.

Key players & programs

Princeton (Seung lab)	Co-led FlyWire and MICrONS; Eyewire [1][2]
Allen Institute and Baylor College of Medicine	MICrONS co-leads [4]
University of Cambridge and FlyWire Consortium	FlyWire partners and proofreading community [3]
Zetta AI	Princeton spin-off doing connectome alignment and proofreading

Frequently asked questions

What is a connectome?
A complete wiring diagram of a nervous system, showing every neuron and the connections between them, usually reconstructed in 3D from electron-microscope images.

What did Princeton's FlyWire map?
Every one of the 139,255 neurons and about 54.5 million synapses in an adult fruit fly brain, published in Nature in October 2024.

What is MICrONS?
A 2025 project co-led by Princeton, Baylor and the Allen Institute that mapped one cubic millimeter of mouse visual cortex, over 524 million synapses and 200,000+ cells, together with recordings of the neurons' activity.

How did AI help map the brain?
Neural networks traced neurons and detected synapses automatically; humans proofread. Without AI, FlyWire would have taken almost 50,000 person-years.

Glossary

Synapse: A connection where one neuron passes a signal to another.

Segmentation: Automatically outlining each neuron in microscope images.

Proofreading: Human correction of errors in automated reconstructions.

Electron microscopy: Imaging with electrons to see structures at nanometer scale.

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