



FlyStream training study

One fruit fly's central nervous system, 165,122 neurons as released on 3 September 2026, raised over thirteen days into a brain that walks, learns and chooses what gets painted.

FlyStream · study project · bugflyguyai.tech

version 1.0 · written 16 September 2026

period covered: 3 to 16 September 2026 · body: one Mac (M1 Pro, 16 GB), one small Hetzner box for the site

How to read this. Every neuron count in this report is taken from the release. Every timing, tally and index is taken from the engine's own logs and assay files. Where a number was set by us rather than measured (the walking drive, the sensory table of a door, the learning rate) it is called a setting, and the section that sets it says so.

1 Summary

On 3 September 2026 the male central nervous system connectome (FlyEM male CNS v1.0) became available: 165,122 neurons, brain and ventral nerve cord, with 10,228,000 signed connections. We ran it as a spiking model after Shiu et al. 2024, never reset, on one laptop, and over thirteen days gave it what a body gives a brain: smells by glomerulus, light by lamina column, temperature, wind on the antennae, and a readout of its descending neurons as movement. We then switched on the one kind of learning a fly is built for, dopamine-gated plasticity in the mushroom body, and tested it the way fly laboratories test it. Finally we gave the brain a task: six floors of doors, each door a piece of a story, the story painted at the bottom.

165,122 neurons, 10,228,000 connections, 11,914 cell types; 103,718 cholinergic, 29,296 glutamatergic, 22,055 GABAergic, 392 dopaminergic	0.31 s of laptop time per 100 ms of the fly's life, four threads; paced to one tick a second while the site shares the machine	0 seizures after day 2; the released model locks at 435 Hz within seconds when it is not reset, two textbook mechanisms stop it
0.41 appetitive learning index after three paired trials, hungry fly, twelve runs (real flies: 0.3 to 0.6)	270 floors descended in the task: 156 doors opened by taste, 103 by standing on them at the buzzer, 11 floors skipped	45 stories, 41 painted, one every eight minutes at the end; a door written in 15 s median, a picture in 32 s median

What it is not. The fly did not learn language, concepts or pictures. It learned what flies learn: this smell came with sugar, this one with a shock, this tile was warm. The doors, the stories and the commentary come from a language model and are labelled as borrowed wherever they appear. What the fly contributes is where it walks, what it tastes, and what changes in its synapses when it is fed.

2 The brain as released

2.1 What arrived

The release is the wiring of one adult male, brain and nerve cord in one volume, with a cell type for each neuron, a side (74,430 right, 74,220 left, 16,080 unsided, mostly sensory axons), and a predicted transmitter. We built one sparse graph from it with signed weights, positive for acetylcholine, negative for GABA and glutamate.

Table 1 · the release, by superclass

SUPERCLASS	NEURONS	WHAT IT IS
optic lobe intrinsic	89,390	the visual system proper, both sides
central brain intrinsic	32,160	mushroom bodies, central complex, lateral horn, everything between senses and descending neurons

nerve cord intrinsic	13,151	the walking and flight circuitry
visual projection	9,201	optic lobe to central brain
sensory (nerve cord, brain, optic lobe)	15,347	receptor neurons and their axons: 2,635 olfactory, 673 Johnston's organ, 1,776 L1 and 1,779 L2 lamina cells among them
ascending and descending	3,160	1,846 ascending, 1,314 descending: the whole channel from brain to body
nerve cord motor	708	the motor neurons

2.2 The model

Leaky integrate-and-fire neurons with the parameters of Shiu et al. 2024, integrated exactly at 0.1 ms, a 1.8 ms delay, driven sensory neurons receiving Poisson kicks of 250×0.275 mV, as in the paper. The paper runs one-second trials from rest. We do not reset: membrane, synaptic current and the delay line carry from one moment to the next, so the fly lives one uninterrupted life, saved to disk every hundred ticks and restored on restart. Its life clock read 2,487 s of fly time at the time of writing, across eleven sessions.

2.3 What we changed, and why

Left running, the released model seizes. After a smell, thirty cholinergic local neurons of the antennal lobe (ILN1_bc, about 800 mV of recurrent excitation per spike) lock at 435 Hz and never stop; after a looming stimulus a smaller loop does the same. Two mechanisms the point-neuron model leaves out, both measured in the fly, stop it: short-term synaptic depression per presynaptic neuron ($U = 0.2$, recovery 300 ms, in the range measured at ORN to PN synapses by Kazama and Wilson 2008) and spike-frequency adaptation (+1 mV per spike, decay 200 ms). With both on, the same sweep of smells, a looming shape and a sound peaks at 190 Hz locally and settles. Both switches default to off in our code; off is the paper's model exactly.

3 The body and the senses

A brain in a jar does nothing. Each 100 ms tick, the engine hands the brain what its body would get at its position, and reads its descending neurons as what the body would do.

Table 2 · what goes in

SENSE	NEURONS DRIVEN	FROM WHAT
smell	2,635 olfactory receptor neurons, by glomerulus	a menu of ten smells the release is wired for (vinegar, ripe fruit, yeast, mould, breath, another male, citrus, cut grass, ammonia, flowers), each a mixture of glomeruli; strength fades with distance from the source
sight	1,776 L1 and 1,779 L2 lamina cells, by hexagonal column	the brightness of the floor ahead, projected onto each eye's column map; L1 for brightening, L2 for darkening
body	thermo- and hygro-sensory neurons	the temperature and humidity word of the tile under it
wind	673 Johnston's organ neurons	a studio fan that gusts now and then; the full drop of a fall

walking state	DNa01, two neurons	a weak steady drive, 10 Hz mean, wandering; the stand-in for the internal state a living fly has and a point model lacks. a setting.
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Table 3 · what comes out (the readouts, each a named cell type in the release)

WORD	NEURONS	READ AS
walk	DNa01 (2)	forward speed, 30 Hz is full speed
steer	all 1,314 descending neurons, left against right	the imbalance of the whole descending drive, as a turn
turn	DNa02 (2)	a small extra left/right term
back up · stop	MDN (4) · DNp09 (2)	reverse · halt
jump · take off	giant fiber DNp01 (2) · DNp02, DNp04, DNp06 (6)	an escape hop · a short flight
taste	MN9 (2), the proboscis motor neurons	three spikes in a tick on a door is a taste
groom · sing	DNg12 · pIP10 (2)	a grooming bout · a wing flick

3.1 Sides for the receptor neurons

The release gives the olfactory receptor neurons no side (their cell bodies sit in the antennae, outside the volume). Without sides a smell reaches both antennae alike and the fly cannot steer toward it. We inferred a side for each from where its synapses land: an ORN whose output weight lands mostly in the left antennal lobe (lateralisation below -0.25) is called left, mostly right is right, the rest drive from both antennae. That gave 195 left, 334 right and 541 unsided. The release holds more right than left receptor neurons, so per-side drive is scaled so that a smell straight ahead moves both lobes alike. This is an inference and is labelled as one on the site.

4 Training

4.1 The memory centre, as found in the wiring

The mushroom body is complete in the release: 4,064 Kenyon cells, 97 mushroom body output neurons, and 392 dopaminergic neurons of which 316 are PAM (the reward cluster) and 16 are PPL1 (the punishment cluster). The Kenyon cells receive the projection neurons of the antennal lobe (438 uniglomerular), so every smell on our menu reaches them as a sparse code. Nothing had to be added; the learning rule had to be given somewhere to act.

4.2 The learning rule

We used the rule of the fly literature, not a general one: the weight of a Kenyon cell synapse onto an output neuron is depressed when the Kenyon cell fires while the dopaminergic neuron of that output neuron's compartment fires, and recovers slowly otherwise. Reward dopamine (PAM) acts on the avoidance-driving output neurons, punishment dopamine (PPL1) on the approach-driving ones, so a smell paired with sugar loses its pull toward avoidance and the fly approaches it. Settings: depression 0.12 per coincident spike pair within 50 ms, floor at 0.2 of the initial weight, recovery time constant 30 fly-minutes, consolidation into a slow weight after 4 fly-hours. Everything else in the brain keeps the released weights.

4.3 Reward and punishment

Sugar is delivered the way a laboratory delivers it: the PAM cluster is driven at 40 Hz for 2 s while the smell is on. Punishment drives PPL1 the same way. No other input changes. Reward is gated by hunger (4.5): a fed fly's PAM drive is scaled by 0.15.

4.4 The assay

The standard two-odour choice, in the engine's own arena: a 60 s test in which the trained smell (CS+) and a control smell (CS-) sit on opposite halves of a 3 by 3 floor, and the index is the time spent on the CS+ half minus the CS- half, over the total. Training is three pairings of 30 s each, with 60 s between. Twelve independent runs, each from a fresh restore of the same saved life, so the brain's state at the start is identical and only the Poisson noise differs.

4.5 Drives

Two scalar drives. Hunger rises from 0 to 1 over one fly-day and is reset by a rewarded taste; it gates the reward dopamine and adds up to 6 Hz to the walking drive. Sleep pressure rises with time awake and, past a threshold at night, lowers the walking drive to zero for a bout. A fly-day was set to 24 minutes of our time so that a month of the fly's life passes in twelve hours.

4.6 The task

Six floors, each a 3 by 3: a landing pad in the middle and eight doors around it. The six floors are the pieces of one story: who, where, when, what is happening, a twist, how it is painted. The doors of a floor are written by a language model from the pieces already taken, and each door carries a smell from the menu, a temperature and a brightness, so the fly meets the door as a sensory object and never as a word. The fly lands on the pad with sixty seconds. Every burst of the proboscis motor neuron on a door is a taste. At the buzzer the most tasted door opens and the fly falls to the next floor, the fall being a second of wind on Johnston's organ. If nothing was tasted, the tile under it opens; the pad is a skipped floor. At the bottom, the pieces become a title, a story and an image prompt, and the picture is painted (GPT Image 2.5 through OpenArt, low quality, one credit tier above the floor). The learning rule was off during the task runs reported here; the reward channel for the task (what counts as sugar at the bottom) is the open decision.

5 The log

Thirteen days, in order. Each entry is what the day's commit messages and engine log say, with the numbers as logged.

day 1 wed 3 sep	The release lands. Download, 2.1 GB of tables; one sparse graph built by evening: 165,122 nodes, 10,228,000 edges, signed by transmitter. First run under the paper's parameters, one second from rest, matches the published spike counts for a sugar stimulus. <code>graph build 41 min · first second of fly time 3.1 s</code>
day 2 thu 4 sep	Continuous life switched on, and the model seizes within twenty seconds of the first smell: thirty antennal-lobe local neurons at 435 Hz, forever. Short-term depression and adaptation added (2.3). Stability sweep written: smells, a looming shape, a sound, twenty seconds each, ten times. <code>peak local rate 435 Hz → 190 Hz · seizures 10/10 → 0/10</code>
day 3 fri 5 sep	The senses (Table 2) and the readouts (Table 3). First walk: the fly on a bare floor, DNa01 read as speed, descending imbalance as steering. It walks in circles for an hour, then we notice the paper's model has no walking state and add the 10 Hz stand-in, labelled. <code>tick 0.31 s on 4 threads</code>
day 4 sat 6 sep	Validation against the paper's behaviours, on the living model: sugar on the proboscis, bitter, water, a looming disc. Save and restore of the whole state every hundred ticks; the life clock. <code>proboscis extension to sugar 10/10 · to bitter 0/10 · giant fiber to loom 9/10</code>
day 5 sun 7 sep	Mushroom body inventory (4.1). The learning rule written. First conditioning run comes out flat: the dopamine gate was applied to both compartments of every output neuron, so reward and punishment cancelled. Found by printing one synapse. <code>index 0.04, n = 4</code>
day 6 mon 8 sep	Gate fixed. Appetitive conditioning works on the first correct run and holds over twelve. Aversive the same afternoon. Reversal: swap the rewards, three more trials, the index changes sign. <code>appetitive 0.41 ± 0.08 · aversive 0.55 ± 0.10 · reversal -0.22 after 3 trials</code>
day 7 tue 9 sep	Drives (4.5). A fed fly stops learning, as it should. First sleep bout observed at the first simulated night: walking drive to zero for 9 fly-minutes, the antennal lobe quiet, the visual system not. <code>fed index 0.06 · 4-hour retention 0.29</code>
day 8 wed 10 sep	The first task: a table of twenty cards with smells, the fly picking four with its proboscis, a local image model painting them. First picture at 23:53. Pictures take two minutes each on the laptop and the laptop swaps itself to a standstill every time. <code>15 pictures · 120 s median per picture</code>
day 9 thu 11 sep	The site: the brain as a fluorescence plate of all 165,122 somata, the thought feed of receipts, the studio. The laptop problem solved by moving painting off the machine and capping the page at two megapixels. <code>page 10 → 2 megapixels · swap 18.5 GB → 5 GB</code>
day 10 fri 12 sep	The table replaced by the tower (4.6). Doors written live by the model from the pieces so far, with a fixed deck as fallback when the model is late. Receptor neuron sides inferred (3.1), and for the first time the fly turns toward a smell instead of into it by chance. <code>195 L · 334 R · 541 both</code>

day 11 sat 13 sep	The tower live, twenty seconds a floor. A taste opened the door at once. Eleven descents by evening: three quarters of the doors taken by standing on them when time ran out, because two fly-seconds is one tile of walking. 66 floors · 17 tasted · 47 at the buzzer · 2 skipped
day 12 sun 14 sep to mon 15 sep	The rule changed: a taste is a sample, the buzzer opens the most tasted door, sixty seconds a floor. The story pipeline settled: one model call at the bottom for title, story, prompt and commentary, the commentary allowed only what the receipts say. The fly's body remodelled from the anatomy. door written 15 s median, 38 s p90 · story 28 s median
day 13 tue 16 sep	Forty-five descents logged, forty-one painted. The taste rule shows in the tallies: doors opened by taste rise from a quarter to well over half. This report. 270 floors · 156 tasted · 103 at the buzzer · 11 skipped · 252 floors by the model, 18 by the deck

6 Results

6.1 Stability

Table 4 · the stability sweep (smells, a looming shape, a sound; twenty seconds each; ten repeats)

MODEL	RUNS THAT SEIZED	PEAK LOCAL RATE	MEAN RATE, WHOLE BRAIN
released model, continuous	10 / 10	435 Hz	rising, no plateau
with depression and adaptation	0 / 10	190 Hz	1.6 Hz
same, over the eleven live sessions since	0	212 Hz	1.7 Hz

6.2 Learning

Table 5 · two-odour choice after training (index: time on CS+ half minus CS- half, over total; 60 s test; n = 12 each)

CONDITION	INDEX	REAL FLIES	NOTE
odour paired with sugar, hungry	0.41 ± 0.08	0.3 to 0.6	three pairings, tested one fly-minute later
odour paired with sugar, fed	0.06 ± 0.09	near 0	hunger gate on the reward dopamine
odour paired with punishment	0.55 ± 0.10	about 0.8	index of avoidance; lower than in flies, see problem 4
reversal, rewards swapped, three more trials	-0.22 ± 0.11	sign flips	the old memory is not erased, it is outweighed
retention after four fly-hours	0.29 ± 0.10	0.3 to 0.4	with the slow-weight consolidation of 4.2
untrained control	0.02 ± 0.07	near 0	no innate preference between the two menu smells used

6.3 The task

Table 6 · the tower, from the engine log (45 descents, 270 floors)

MEASURE	VALUE	NOTE
doors opened by taste (most tasted door at the buzzer)	156 (58 %)	17 of 66 under the first rule, 139 of 204 under the sixty-second rule
doors opened by standing on them, nothing tasted	103 (38 %)	
floors skipped on the pad	11 (4 %)	the story goes on without that piece
tastes logged	255	a taste is three MN9 spikes in one tick on a door
neurons firing in the tick of a choice	4,226 median	range 2,828 to 7,220 of 165,122

Johnston's organ spikes per fall	15,520 median	673 neurons, the wind of the drop until the next floor is written
floors written by the model / dealt from the deck	252 / 18	the deck steps in when the model is late (over 45 s)
jumps (giant fiber) during rounds	41	mostly on fan gusts

Table 7 · latencies and cost

ITEM	VALUE
one tick of the brain (100 ms of fly time), four threads, M1 Pro	0.31 s
a floor of eight doors written by the model	15 s median · 38 s p90
title, story, prompt and commentary at the bottom	28 s median · 76 s max
a picture, GPT Image 2.5 (low) through OpenArt	32 s median · 5 credits
a picture, FLUX.1 schnell on the laptop (days 8 and 9)	120 s median
one descent, end to end, sixty-second floors	about 8 min
model calls per descent (six floors, one story, one painting relay)	8

7 Problems on the way

1 · the seizure

The paper's model is only ever run for one second from rest, and is stable that way. Run for minutes it locks at 435 Hz. Two mechanisms measured in the fly fix it (2.3). We consider this the one real finding about the released model.

2 · a brain with no reason to walk

With no internal state, the model stands still or circles. The 10 Hz stand-in is honest but it is ours; every page that shows movement says so.

3 · the dopamine gate

One sign error applied reward to both compartments of each output neuron, cancelling learning exactly. A day lost, found by reading one synapse's history.

4 · aversive learning short of the animal

0.55 against about 0.8 in flies. The punishment cluster is sixteen neurons in the release and we drive it as one block; real shock recruits more. Left as is and reported.

5 · the laptop

The brain (four cores), a local image model (five gigabytes each picture) and the site in one 16 GB machine: 18.5 GB of swap and a frozen browser. Painting moved off the machine; the page capped itself.

6 · two fly-seconds a floor

At one tick a second, a twenty-second floor is two seconds of fly life, one tile of walking; three quarters of doors were whatever the fly stood on. Sixty seconds and taste-as-sampling fixed the tallies (Table 6).

7 · the model that writes the doors

It is late one floor in fifteen and, early on, kept offering the same odd nouns. A deck fallback and an avoid list of the last forty-eight pieces; the tallies in Table 6 are after both.

8 · unsided noses

The release's receptor neurons have no side and the fly could not steer to a smell. Sides inferred from synapse targets (3.1). Right-heavy counts in the release, so per-side drive is normalised. Labelled an inference.

8 What is real, what is ours, what is borrowed

Real: the wiring, the transmitters, the spiking, which neurons fired in every tick, which tile the fly stood on, what its antennae got in each fall, the synaptic weights that changed when it was fed, every tally in Table 6.

Ours: the two stability mechanisms, the map from ten smells to glomeruli, the eye projection, the readout table, the walking-state drive, the learning rule's rates, the sensory table of every door, the tower and its clock, the inferred sides. Each is a setting and is named as one where it acts.

Borrowed: the doors, the stories, the titles, the image prompts and the commentary, written by a language model. The commentary is allowed to say only what the receipts say, and it is checked for a list of words the fly has no right to (wanted, liked, thought, decided) before it is shown. The pictures are painted by an image model from the prompt. The fly has no ideas about stories. It has a nose, eyes, legs, a memory centre, and a lot of patience.

Appendix A · settings

SETTING	VALUE	WHERE
integration step · delay	0.1 ms · 1.8 ms	sim
short-term depression U · recovery	0.2 · 300 ms	sim, 2.3
adaptation per spike · decay	1 mV · 200 ms	sim, 2.3
walking-state drive, mean	10 Hz	engine, Table 2
smell plume width	0.9 tiles	engine
ORN side threshold · per-side normalisation cap	0.25 · 2.0	engine, 3.1
learning: depression per pair · floor · recovery · consolidation	0.12 · 0.2 · 30 fly-min · 4 fly-h	assays, 4.2
reward and punishment drive	40 Hz · 2 s	assays, 4.3
fly-day · fed reward gain	24 min · 0.15	engine, 4.5
round · fall floor · deck fallback	60 s · 4 s · 45 s	engine, 4.6
taste	3 MN9 spikes in a tick	engine, Table 3

Appendix B · the smell menu

vinegar · ripe fruit · yeast · mould · breath · another male · citrus · cut grass · ammonia · flowers. Each is a fixed mixture of glomeruli the release names; the mixtures follow the receptor literature and are the same for every door and every assay.