synaptic connections with a subset of cholinergic pC1 neurons (a cluster of neurons in the central brain that have previously been linked to sexually dimorphic behaviours) and that photoactivation of SAG neurons depolarized these cells. Ablating these pC1 cells increased egg laying in virgin female flies, whereas chronic activation of the pC1 cells reduced egg laying in mated females. Photoactivation of pC1 cells resulted in hyperpolarization of oviDNs, supporting the idea that they act upstream of oviDNs to suppress their function and prevent egg laying in virgin females.

The authors identified two sets of interneurons that provide direct synaptic input to oviDNs, which they termed oviposition excitatory neurons (oviENs) and oviposition inhibitory neurons (oviINs). As expected, oviEN activation promoted egg laying in virgin females, whereas oviIN activation suppressed egg laying in mated females. The authors showed that oviINs are reciprocally connected to and potentiated by pC1 cells, suggesting that oviINs may act as an intermediate in the pathway through which mating status regulates egg laying.

Unlike oviINs, oviENs were not directly connected to pC1 cells; however, the authors showed that these cells responded specifically to the presentation of a substrate (agarose) on which the flies preferred to lay their eggs, suggesting that they may act to regulate egg laying in response to external sensory cues. The authors suggest that the oviDNs integrate the oviIN and oviEN inputs to combine the separate influences of mating status and substrate, ensuring that eggs are laid at the optimal time and place.

In this study, the authors have identified and characterized a number of the key components regulating egg laying in flies, providing insight into the mechanisms that coordinate the timing and location of complex reproductive behaviours.

*Katherine Whalley*

**ORIGINAL ARTICLE** Wang, F. et al. Neural circuitry linking mating and egg laying in *Drosophila* females. *Nature* **579**, 101–105 (2020)

response to increased network activity seemed contrary to the notion of homeostasis. The authors reasoned that this might be because, rather than being inhibitory, GABA is still excitatory at the ChC–AIS synapse at P12–P18. Indeed, they found that in acute slices taken at P14–P18, GABA presented at the AIS of pyramidal neurons expressing a genetically encoded voltage indicator induced a response that indicated depolarization. These findings suggest that ChCs monitor network activity and adjust their output in a homeostatic manner.

Homeostatic mechanisms are generally reversible. To test this, the authors chemogenetically stimulated ChCs for 6 days followed by 5 days of no stimulation. At the end of this period, all measures of axo-axonic synaptic connectivity had returned to the same levels as unstimulated control neurons, consistent with the principles of homeostatic plasticity.

As mentioned earlier, GABAergic synapses switch polarity during development, and to test this at the ChC–AIS synapse, the authors performed voltage imaging of pyramidal neurons in acute cortical slices from P40 mice. GABA presented at the AIS produced either a hyperpolarizing response or no response, indicating that GABA was no longer depolarizing. The authors reasoned that, if ChCs continue to perform a homeostatic role in older animals, then increasing network activity should induce the opposite phenotype in the older animals to that seen in the developing animals. Indeed, following chemogenetic activation of pyramidal neurons at P40–P46, the authors observed a small increase in the overall number of axo-axonic synapses.

Together, these data indicate that ChC interneurons may act in a homeostatic manner to regulate hyperactivity in cortical circuits by reducing axo-axonic synapses earlier in development, when GABA is excitatory and increasing these synapses later in life, when GABA is inhibitory.

*Sian Lewis*

**ORIGINAL ARTICLE** Pan-Vazquez, A. et al. Activity-dependent plasticity of axo-axonic synapses at the axon initial segment. *Neuron* https://doi.org/10.1016/j.neuron.2020.01.037 (2020)

# IN BRIEF

## PERCEPTION

### Bees can touch but not look

Many animals can recognize objects they have previously felt but not seen, and vice versa. Whether invertebrates can generate cross-modal internal representations for such tasks is unknown. Solvi et al. trained bumble bees in the dark to discriminate between spheres and cubes, and then tested their visual discriminative ability for the same objects that could only be seen (in the light) through a clear barrier, and not touched. Bees spent more time with objects in the light that had been previously rewarded in the dark. Conversely, bees trained to visually discriminate the objects spent longer with the objects in the dark (tactile) setting. Thus, bees can use cross-modal integration to recognize objects.

**ORIGINAL ARTICLE** Solvi, C. et al. Bumble bees display cross-modal object recognition between visual and tactile senses. *Science* **367**, 910–912 (2020)

## CELLULAR NEUROANATOMY

### A close-up of connectivity

Understanding a neuron's function requires a full assessment of its inputs and outputs, which can be challenging for neuronal types with intermingled inputs and outputs. Morgan and Lichtman reconstructed a mouse thalamic local interneuron they called LIN1 from electron microscopy data and mapped its connectivity. They identified 899 synaptic inputs from and 623 synaptic outputs to different cell types, implicating LIN1 in many types of interaction 'motif'. Each interneuron in this class may therefore perform all of the functions ascribed to this class.

**ORIGINAL ARTICLE** Morgan, J. L. & Lichtman, J. W. An individual interneuron participates in many kinds of inhibition and innervates much of the mouse visual thalamus. *Neuron* https://doi.org/10.1016/j.neuron.2020.02.001 (2020)

## STRESS

### Hot and bothered

The dorsomedial hypothalamus (DMH) drives the responses of the sympathetic nervous system to psychosocial stress; however, its inputs are not well understood. Kataoka et al. identified inputs to the rat DMH from the dorsal peduncular cortex and dorsal tenia tecta (DP/DTT). Social defeat stress induced cardiovascular and thermogenic sympathetic stress responses that were diminished by pharmacological or optogenetic inactivation of the DP/DTT, and mimicked through photostimulation of the DP/DTT. This DP/DTT–DMH circuit could be a potential target for treating stress-related disorders.

**ORIGINAL ARTICLE** Kataoka, N. et al. A central master driver of psychosocial stress responses in the rat. *Science* **357**, 1105–1112 (2020)

## REWARD

### Ride the wave for reward

The role of theta oscillations in the orbitofrontal cortex during reward-guided behaviour is unknown. Here, Knudsen and Wallis used closed-loop control to record these oscillations to enable disruptive microstimulation of the oscillations in two macaques trained in a two-alternative forced-choice task in which reward contingencies were gradually changed over a number of trials. The phase alignment of theta oscillations between trials increased during value-updating trials, particularly during the fixation epoch. Disruption of theta during this epoch impaired the animals' ability to update their choices, implicating these oscillations in value updating.

**ORIGINAL ARTICLE** Knudsen, E. B. & Wallis, J. D. Closed-loop theta stimulation in the orbitofrontal cortex prevents reward-based learning. *Neuron* https://doi.org/10.1016/j.neuron.2020.02.003 (2020)