This Week in The Journal

HCN Channels May Trigger Persistent Spiking in Dentate Gyrus

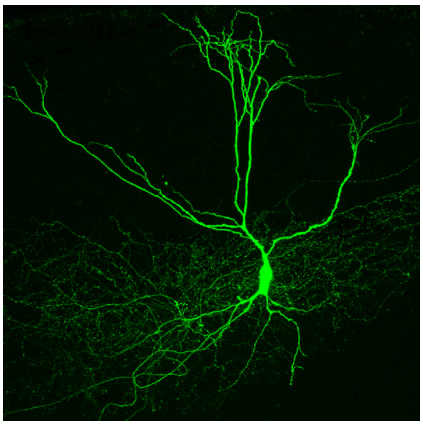
Claudio Elgueta, Johannes Köhler, and Marlene Bartos

(see pages 4131–4139)

In the traditional model of neurons, excitatory inputs to dendrites cause depolarization that spreads across the soma to the axon initial segment, where, if a threshold is surpassed, an action potential is generated. There are many exceptions to this general rule, however. Some neurons exhibit rebound spiking when freed from inhibition and others produce spike trains without additional synaptic input when depolarized above a plateau potential. In addition, recent studies revealed that some neurons enter a persistent firing mode after receiving prolonged, high-frequency stimulation. For example, repeated stimulation of interneurons in hippocampal CA1 led to persistent firing in which action potentials were generated in the distal axon (Sheffield et al., 2010, Nat Neurosci 14:200).

Elgueta et al. report that a similar phenomenon occurs in perisomatic inhibiting interneurons (PIIs) targeting granule cells in the dentate gyrus. Persistent firing was induced by repeatedly injecting long current steps into PII somata, evoking spike trains at 30–100 Hz, stimulating perforant-path inputs to PIIs at 30 Hz, or producing antidromic action potentials by extracellularly stimulating PII axons. Persistent firing averaged ~50 Hz and typically lasted ~4.5–20 s. Spike shapes suggested that persistent firing in dentate PIIs, like in CA1 interneurons, originated in the distal axon. Consistent with this, optically silencing axons for 5 s greatly reduced the duration of persistent firing. The mechanisms underlying the induction of persistent firing appear to differ in CA1 and dentate gyrus, however. Whereas activation of voltage-gated Ca^{2+} channels enhanced persistent firing in CA1 interneurons, blocking these channels enhanced persistent firing in dentate PIIs.

Interestingly, brief axonal hyperpolarization increased the duration of persistent firing, suggesting that hyperpolarization-activated cyclic-nucleotide-gated ion channels (HCNCs) contribute to the phenomenon. Indeed, although it seems counterintuitive that hyperpolarization-activated channels would be activated during high-frequency firing, persistent firing could not be induced in the presence of HCNC inhibitors. The authors hypothesized that accumulation of cAMP during high-frequency stimulation causes a depolarizing shift in the activation curve of HCNCs. A computational model confirmed that such a shift can lead to persistent firing. The induction of persistent firing in inhibitory neurons might prevent pathological hyperactivity after prolonged activation of neural networks.



A dentate gyrus PII that shows persistent firing after prolonged activation. See the article by Elgueta et al. for details.

Bee Pheromones Are Processed by Separate Neural Pathways

Julie Carcaud, Martin Giurfa, and Jean-Christophe Sandoz

(see pages 4157–4167)

Odorant molecules bind to receptors on olfactory sensory neurons (OSNs), which transmit information to glomeruli in the first olfactory processing site in the CNS. In most species, each OSN expresses a single olfactory receptor type and all OSNs converging on a single glomerulus express the same receptor. But because most olfactory receptors bind multiple molecules and most odorants activate multiple receptors, odor representations are typically distributed across multiple glomeruli in a combinatorial code. Some pheromones are an exception to this rule, however. For example, honey bee drones express an olfactory receptor that responds only to a component of queen retinue pheromone (Wanner et al., 2007, Proc Natl Acad Sci U S A 104:14383). This component likely activates a single glomerulus in the bee antennal lobe (AL), and because projection neurons (PNs) that transmit information from the AL to higher processing areas typically innervate a single glomerulus, some PNs probably respond selectively to this one pheromone component. This labeled-line organization might ensure that drones respond reliably to the queen pheromone.

Honey bees use a wide variety of pheromones to induce diverse behaviors such as tending the queen and brood, aggregating in swarms or at the hive entrance, and attacking intruders. Therefore, they are a valuable model system for studying the neural bases of pheromone responses. To determine whether labeled lines are commonly used for pheromone coding in honey bees, Carcaud et al. used Ca^{2+} indicators to selectively label PNs that projected in the medial or lateral antennal lobe tracts (m-ALT and l-ALT, respectively). Consistent with the labeled-line hypothesis, components of queen mandibular pheromone elicited strong signals only in l-ALT PNs, whereas most brood pheromone components elicited activity only in m-ALT PNs. In contrast, components of other queen pheromones and most components of worker alarm and aggregation pheromones elicited significant activity in both tracts. Furthermore, all pheromones elicited activity in multiple glomeruli, and most of these glomeruli responded to multiple pheromones.

While these data indicate that honey bee queen and brood pheromones are processed in distinct neural pathways, they suggest most pheromones are not coded by labeled lines. Nonetheless, the results provide a foundation for future studies of the neural pathways underlying pheromones' ability to induce specific behaviors.

This Week in The Journal is written by Teresa Esch, Ph.D.