The ability to navigate through the environment using chemical cues is essential for survival across species, from bacteria to insects to mammals. Landmarks in the environment can manifest as discrete objects or as continuous fields like chemical gradients and airflow patterns, presenting the brain with the challenge of binding representations generated by visual, somatosensory, and chemical cues. Animals across phyla have evolved sophisticated neural systems for detecting, processing, and remembering spatial relationships between odors and environmental features. Understanding how the brain constructs a unified representation of space from these diverse sensory inputs has been a central goal of neuroscience. The hippocampus generates cognitive spatial maps through place cells, and recent work has revealed that spatial information is also represented in the piriform cortex through place-cell-like activity, suggesting the olfactory system plays a key role in spatial navigation and memory.

However, it remains relatively unclear how spatial information is represented in the olfactory bulb (OB), the first central relay of olfactory processing. While the OB receives extensive feedback from hippocampal circuits, we do not understand how this top-down input shapes spatial representations in the olfactory system or how the loss of bottom-up olfactory input affects spatial coding across this network.

The objective of this proposal is to characterize how spatial information is encoded in the olfactory bulb and determine how it interacts with hippocampal spatial circuits. Our central hypothesis is that spatial representations in the OB emerge through integration of both bottom-up sensory input and top-down hippocampal feedback.

Specific Aim 1: Determine how olfactory input shapes spatial representations across the olfactory-hippocampal network. We will record simultaneously from OB and hippocampus while mice explore a "grid world" arena in search of covert targets, then examine how spatial representations in these brain regions change following chemically-induced anosmia. We hypothesize that in the absence of olfactory input, OB spatial representations will show increased dependence on hippocampal signals.

Specific Aim 2: Characterize the spatial resolution of olfactory memory and its neural correlates. We will record from OB and hippocampus while mice perform a spatially-precise odor memory task. The spatial resolution of OB place fields will correlate with behavioral performance, with more precisely-tuned cells emerging as mice learn to localize odors with sub-centimeter accuracy.

This research will provide fundamental insights into how the brain creates integrated representations of space and odor. Understanding how the olfactory system contributes to spatial navigation and memory has implications for both basic neuroscience and clinical applications, as impaired olfactory-spatial processing is an early indicator of neurodegenerative conditions.