Summary

In this thesis I investigated anatomical and functional principles of odor encoding in projection neurons underlying olfactory learning and olfactory-guided behaviors in the honeybee. To this purpose, I performed electrophysiological recordings of projection neuron odor responses. Furthermore, I developed new techniques to compose single projection neurons labeled in separate specimens within one common framework, the ‘Atlas of the Honeybee Brain’. In relation to olfactory-guided behaviors of the honeybee I examined the differences of elemental structures within the microcircuitry of the projection neuron output region in groups of animals which had experienced different odors in a particular behavioral context. The results of my thesis reveal important aspects of functional and anatomical features underlying olfactory learning and olfactory-guided behaviors.

I A standard Atlas of the Honeybee Brain was created as an average-shape calculated from 20 individual immunostained whole-mount bee brains. After correction for global size and positioning local differences by repeatedly applying an intensity-based nonrigid registration algorithm were adjusted and a sequence of average label images was created. The results were qualitatively evaluated by generating average gray-value images corresponding to the average label images and judging the level of detail within the labeled regions. Registering neurons from different preparations into the standard atlas reveal their anatomical features which allow to draw conclusions about the connectivity within the entire network of

the honeybee brain. Thus the standard atlas and the procedures applied for registration serve the function of creating realistic neuroanatomical models of parts of a neural net.

II Since the honeybee exhibits an elaborate behavior associated with the perception of complex natural stimuli, the representation of odor mixtures in relation to neuronal morphology within its brain was studied. To understand mixture representation within the honeybee brain electrophysiological recordings of single olfactory interneurons within the first-order relay station of the olfactory pathway, the antennal lobe were performed. The results of this study show that antennal lobe output neurons of the lateral antenno-cerebral tract (lACTs) convey odor mixture information onto the second-order relay station of the olfactory pathway, the mushroom bodies whereas antennal lobe output neurons of the median antenno-cerebral tract (mACTs) transfer odor identity information. The 3-D composition of single l-, and mACTs within a spatial reference map, the 'Atlas of the Honeybee Brain', reveal their uniglomerular input functionally represented by glomerulus-specific olfactory response. The spatial distribution of their axon terminals (boutons) within their output region, the mushroom body lips appears largely segregated between l- and mACTs and density-dependent among the mACTs. Thus the results of this study show that glomerulus-specific input within the antennal lobe is either represented by an area-dependent (lACTs) or a density-dependent (mACTs) bouton topography within the mushroom body lips.

III Worker honeybees proceed through a sequence of tasks, passing from hive and guard duties to foraging activities. However, the underlying neuronal changes mediating these behavioral transitions are not yet understood. Previous studies have shown that the mushroom bodies (MB), a brain region involved in sensory integration, learning and memory, undergo a volumetric expansion throughout adult life. This study was designed to reveal the mechanisms underlying MB structural changes by investigating age-, task-, and experience-dependent structural plasticity of microglomerular complexes in the lips of the MB, which exclusively process olfactory information. By applying simultaneous labeling of presynaptic olfactory projection neuron boutons and postsynaptic Kenyon cell spines microglomerular complexes (MC) could be visualized and analyzed with 3-D stereological techniques. The results of this study reveal that continuity of developmental and behavioral maturation leads to structural plasticity expressed as an increase in MB lip volume, MC number and bouton size. Manipulations of age-related sensory perception induce degrading compensatory structural plasticity effects represented by a decrease in MC number and an increase in bouton size.