Universität Basel

Research Project

The organisation and function of long-range projections in visual cortex

Third-party funded project

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Our senses are constantly bombarded with a vast amount of information. To perceive this information and to guide behaviour, the brain must extract and amplify a relatively small number of features from this massive input, corresponding for example to the nature and location of objects in the world. In mammals, the cerebral cortex plays a central role in this process. The cortex contains multiple hierarchically-arranged areas devoted to each modality. Each cortical area contains a richly interconnected array of diverse cell types, whose patterns of connectivity underlie the cortex's ability to extract sensory features or generate more complex representations of the external world. While connections between nearby neurons mediate local information processing within each cortical region, extensive long-range projections mediate the exchange of information between cortical areas specialised in different functions. Surprisingly little is known about the rules of connectivity and resulting computations in long-range circuits that link cortical areas. This knowledge may be crucial for developing a conceptual framework of what the cortex actually computes and how it computes it within hierarchically organised cortical networks. The proposed research aims to understand the fundamental anatomical organizational principles of long-range neuronal circuits in the visual cortex, comprised of multiple distinct types of projection neurons, and how this organization relates to their molecular identity and the information they represent during visual processing. We focus on the visual cortex of the mouse using a combination of methods, including anatomical labelling and reconstructions of long-range projection neurons, two-photon calcium imaging of neuronal activity in awake or behaving mice, assessment of connectivity by in vitro whole-cell recordings and optogenetics, single-cell transcriptomics of anatomically and functionally characterised neurons, in vivo optogenetics, and visual behavioural tasks. The research plan outlined in this proposal with address the following main aims: (i) What is the fine-scale anatomical organisation of long-range circuits in primary visual cortex? We will focus on uncovering the diversity and connectional logic of excitatory projection neurons that transmit information from visual cortex to downstream cortical areas. (ii) What visual information is represented by diverse projection neurons in primary visual cortex during visual processing? We will determine how the visual response properties of different types of projection neurons relate to the cortical areas they target, and how their activity is modulated by intra-cortical feedback while mice engage in different behavioural tasks requiring vision. (iii) What are the molecular determinants of long-range connectivity and function of projection neurons in primary visual cortex? We will test the hypothesis that there is relationship between the molecular identify of projection neurons on one hand, as determined by their transcriptional profile, and the target areas they innervate as well as their visual response properties on the other. Together, this work will provide an insight into the fine-scale organisation and function of long-range cortical circuits, which is crucial for understanding information processing across different cortical areas. This knowledge may be used to uncover what goes wrong in

neurological disorders in which inter-areal communication is compromised, such as Schizophrenia and autism. Each cortical area contains a richly interconnected array of diverse cell types, whose patterns of connectivity underlie the cortex's ability to extract sensory features or generate more complex representations of the external world.ă

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