From Maps to Circuits
Models and Mechanisms for Generating Neural Connections

Informatics Forum, Edinburgh, Scotland

28–29 July 2014

Introduction

Welcome to the `http://maps2014.org` workshop. If there are any changes to the programme, please check the website for updates, where you can find a copy of this pdf:

`http://maps2014.org/maps2014_prog.pdf`

(This is Revision: 1.15)

Catering All food and drink breaks listed in the programme will be hosted in the Informatics building. All catering on Monday and Tuesday is included in the cost of the workshop.

Posters Posters can be put up Monday morning and left up for the duration of the meeting. The formal poster session will be Monday evening. Posters can be A0 landscape. We will have some prizes for best posters. You will get a voting paper upon registration with details.

Sunday 27th July evening For anyone arriving on Sunday, we will have an informal gathering in "The Southern" bar, 22–26 South Clerk Street, EH8 9PR (`http://www.thesouthern.co.uk`). You can get food here. Come along after about 19:30 / 20:00 and hopefully you'll meet someone else attending the workshop.

Wireless access EDUROAM is available in the Informatics Forum.

Monday 28th July 2014

09:00 *Registration (tea and coffee available).*

09:15 *Session 1.*

Michael Crair, Yale University
Activity-dependent map development prior to sensory experience

Geoffrey Goodhill, University of Queensland
Axon guidance and visual maps: novel methods for data analysis

10:45 *Tea break.*

11:15 *Session 2.*

Robert Hindges, Kings College London
Competition and plasticity during mammalian topographic map formation

Fred Wolf, Max Planck Institute for Dynamics and Self-Organization, Göttingen

12:45 *Lunch.*

14:00 *Session 3.*

Hitoshi Sakano University of Tokyo
Neural Map Formation in the Mouse Olfactory System

Thomas Clandinin, Stanford University
How networks of adhesion determine the fine structure of the brain

15:30 *Tea break.*

16:00 *Session 4.*

Christoph von der Malsburg, Frankfurt Institute for Advanced Studies
Self-organization of control circuits for multiple topological mappings

16:45 *Discussion.*

17:30 *Poster session.*

19:00 *Dinner.*

Tuesday 29th July 2014

09:00 *Coffee.*

09:15 *Session 5.*

David Wilkinson, National Institute for Medical Research, London
Experimental and computational approaches to Eph-ephrin mediated cell segregation

Uwe Drescher, Kings College London
Target-independent ephrinA/EphA-mediated axon-axon repulsionas a novel element in retino-collicular mapping

10:45 *Tea break.*

11:15 *Session 6.*

Irina Erchova, Cardiff Univeristy
Dark exposure promotes recovery of neuronal responses in binocular visual cortex of adults mice after juvenile monocular deprivation

Sonja Hofer, Basel
The development of functional microcircuits in visual cortex

12:45 *Lunch.*

14:00 *Session 7.*

David Willshaw, Edinburgh University
Analysis of single and double visual maps in mouse

David Feldheim, UC Santa Cruz
Map formation in the mammalian superior colliculus

15:30 *Discussion and closing words.*

16:00 *Tea and depart*

Talk abstracts

How networks of adhesion determine the fine structure of the brain

Thomas Clandinin, Stanford University

Neuronal growth cones select synaptic partners through interactions with multiple cell surfaces in their environment. Many of these interactions are adhesive, yet it is unclear how growth cones integrate adhesive cues to direct their movements. In the Drosophila visual system, genetic programs hardwire the development of synaptic specificity with single cell resolution and remarkably fidelity. We show that differences in adhesion between groups of neighbouring cells act coordinately to specify multiple steps in axonal and dendritic targeting.

Activity-dependent map development prior to sensory experience

Michael Crair, Yale University

The refinement of exuberantly projecting neural circuits into ordered maps is a common feature of developing vertebrate nervous system. In sensory systems, patterned spontaneous activity before the onset of sensation is thought to influence this process, but this conclusion remains controversial largely due to the inherent difficulty in recording and manipulating neural activity during early development. Beyond sensory systems, there is little evidence for the presence of patterned spontaneous activity, and almost nothing is known about its role in neural circuit development. We will describe novel genetic, pharmacological and optical imaging approaches to examine and manipulate spontaneous activity in vivo to establish a causal link between activity and neural circuit refinement. Our experiments extend beyond the visual system to the entire developing neocortex to suggest that patterned spontaneous activity is a ubiquitous phenomenon in early brain development. Intrinsically generated spontaneous activity prior to sensory experience may play a fundamental role in the development and refinement of neural maps throughout the brain, and disruptions in this activity could be related to the pathophysiology of a variety of neurodevelopmental disorders, including epilepsy and autism.

Target-independent ephrinA/EphA-mediated axon-axon repulsionas a novel element in retino-collicular mapping

Uwe Drescher, Kings College London

EphrinAs and EphAs play critical roles in topographic map formation in the retino-collicular projection; however, their complex expression patterns on both retinal ganglion cell (RGC) axons and in the superior colliculus (SC) have made it difficult to uncover their precise mechanisms of action. Use of a conditional ephrinA5 knockout has enabled us now to better understand the role of ephrinA5 on RGC axons versus its function in the SC. Surprisingly, temporal axons show no major targeting defects when ephrinA5 is removed from the SC alone, but we observe substantial mapping defects, with temporal axons invading the target areas of nasal axons, when in addition retinal ephrinA5 expression is abolished. This indicates that ephrinA5 on RGC axons drives repellent interactions between temporal and nasal axons during topographic mapping within the SC, and demonstrates for the first time that target-independent mechanisms play an essential role in retino-collicular map formation in vivo.

Dark exposure promotes recovery of neuronal responses in binocular visual cortex of adults mice after juvenile monocular deprivation

Irina Erchova, Cardiff Univeristy

Neuronal connections in the brain are shaped by sensory and motor experience predominantly during "critical period" in early life. An abnormal experience during this period leads to circuit malformation and long lasting sensory deficits that are difficult to repair later in life. Monocular deprivation (MD) disrupts normal visual input and causes changes in binocular visual cortex,

such as loss of contralateral eye dominance and orientation selectivity. The deficits are most severe when deprivation initiated during the critical period and binocular vision is not restored until adulthood. In my talk I would discuss differences between effects of juvenile and adult MD on neuronal responses in binocular cortex and beneficial effects of dark exposure leading to partial recovery of normal neural responses. Our results suggest that dark exposure activates homeostatic mechanisms and re-scaling of visual responses and thus enables a much greater degree of adult plasticity.

Map formation in the mammalian superior colliculus

David Feldheim, UC Santa Cruz

The organisation of sensory inputs into topographic maps and the subsequent integration of these maps in associative areas in the brain is a fundamental feature of neural processing. Understanding how features from distant sources are integrated in the brain is essential toward understanding the molecular and activity dependent mechanisms of neurological diseases such as ADHD, dyslexia, and autism. The SC receives inputs directly from the retina, via a number of distinct functional types of retinal ganglion cells (RGCs), and indirectly from cortical and brainstem areas and uses this information to control reflexive head and eye movements. Each distinct input forms synaptic connections in different layers of the SC, creating its stereotypical laminated structure. Furthermore, each of the layers is retinostopically organised and is in register with the others. Here I present data and my current understanding of the mechanisms responsible for the formation of topographically aligned inputs in the mouse SC.

Axon guidance and visual maps: novel methods for data analysis

Geoffrey Goodhill, University of Queensland

I will discuss the following two topics. 1) Growth cones play a critical role in guiding axons to their targets. Growth cones have a complex and dynamic morphology, yet there has been little quantitative analysis of their shape dynamics. I will show how eigenshape analysis can yield insights into this. 2) Gaussian process (GP) methods have recently been proposed as a better technique than vector averaging for extracting structure from intrinsic signal optical imaging data or orientation maps in V1 than traditional vector averaging. I will show how GP methods can be extended to the analysis of maps from animals raised with altered visual experience, and the new insights this provides, and to correlated maps of multiple feature preferences.

Competition and plasticity during mammalian topographic map formation

Robert Hindges, Kings College London

The establishment of topographic maps is a fundamental process during the development of visual connectivity. In mouse, retinal ganglion cell (RGC) axons project from the eye to their main target, the superior colliculus (SC). Axons initially overshoot their appropriate targets and only through subsequent refinement finalize their projections. In addition to the strict topographic arrangement of these projections, there are laminar targeting differences, where axons from the contra- and ipsilateral eye terminate in superficial and deep layers of the SC, respectively. The formation of this retinotopic map depends on the action of axon guidance molecules, activity-dependent mechanisms and axonal competition. However, little is known about the plasticity potential of the system and the effects of retinal insults on the remodeling of retinocollicular connections. Here, we created a mouse model in which RGCs that specifically project to anterior and posterior SC undergo cell death during topographic map formation. We show that the remaining RGCs expand the targeted area in the SC and at the same time increase their spatial coverage in the retina in a correlated fashion. The resulting contralateral topographic map is overall maintained but less precise, while ipsilateral RGC axons are abnormally distributed in anterior and posterior superficial SC. These results suggest the presence of plastic mechanisms in the developing mammalian visual system to adjust retinal space and its target coverage to ensure a uniform

map. In addition, our model describes the roles of competition at several different points during the development of the retinotopic projection.

Self-organization of control circuits for multiple topological mappings

Christoph von der Malsburg, Frankfurt Institute for Advanced Studies

Assuming that patterns in memory are represented as two-dimensional arrays of local features, just like they are in primary visual cortices, pattern recognition can take the form of elastic graph matching. Neural implementation of this may be based on pre-organized fiber projections that can be activated rapidly with the help of control units. Each control unit governs a set of projection fibers that form part of a coherent mapping. I describe a mechanism for the ontogenesis of the underlying connectivity based on a principle of network self-organization. Simulations illustrate the growth of invariant point-to-point and feature-to-feature mappings.

Neural Map Formation in the Mouse Olfactory System

Hitoshi Sakano University of Tokyo

In the mouse olfactory system, odorants are detected with ∼1,000 different odorant receptor (OR) species expressed in the cilia of olfactory sensory neurons (OSNs). Each OSN in the olfactory epithelium (OE) expresses only one functional OR gene in a mutually exclusive and mono-allelic manner. Furthermore, OSNs expressing the same OR species converge their axons to a specific location in the OB forming a glomerular structure. Because a given OR responds to multiple odorants and a given odorant activates multiple OR species, the odor information detected in the OE is topographically represented as the pattern of activated glomeruli in the OB[1].

A remarkable feature of axonal projection in the mouse olfactory system is that ORs play an instructive role in projecting OSN axons to the OB. For dorsal-ventral (D-V) projection, anatomical location of OSN cells within the OE regulates both OR gene choice and expression levels of axon guidance molecules, thus indirectly correlating the OR identity to the glomerular location along the D-V axis[2]. In contrast, anterior-posterior (A-P) projection is totally independent of the positional information of OSN cells, but instead dependent on the expressed OR species. We have previously reported that A-P targeting is regulated by OR-derived cAMP signals[3]. In the OB, A-P projection molecules are detected on axon termini of OSNs, forming a complementary gradient in the glomerular map[4].

OR-derived cAMP signals also regulate the expression of glomerular segregation molecules[5] for the map refinement through local sorting of OSN axons. Unlike A-P projection molecules, glomerular segregation molecules show mosaic distribution in the glomerular map. Naris occlusion experiment indicated that stimulus-driven neuronal activity contributes to the local sorting of OSN axons, but not to global targeting along the A-P axis[6].

How is it, then, that global A-P targeting and local sorting are differentially regulated by the expressed OR molecules using cAMP as a second messenger? What are the sources of the cAMP signals? How is the map interpreted in the central brain for behavioural decision[7]? Here, we discuss the recent progress in the neural map formation in the mouse olfactory system.

References

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