EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

Public Relations Department

Dr. Karl Guido Rijkhoek
Director

Antje Karbe
Press Officer
Phone +49 7071 29-76788
+49 7071 29-76789
Fax +49 7071 29-5566
karl.rijkhoek[at]uni-tuebingen.de
antje.karbe[at]uni-tuebingen.de

www.uni-tuebingen.de/aktuell

Press Release

A Sense of Direction in the Brain: Seeing the Inner Compass

Head direction cells in rodents are directly connected with other neuronal structures used in navigation, most importantly the 'grid cell area'

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A team of neuroscientists led by Dr. Andrea Burgalossi of the Tübingen Werner Reichardt Centre for Integrative Neuroscience (CIN) at the University of Tübingen have taken an important step towards understanding the 'inner compass'. Investigating so-called head direction cells (HD cells) in the rodent brain, they were able to find evidence of networks that had been purely theoretical for more than a decade: HD cells are directly linked with different types of brain structures that control navigation. Most intriguingly, they forward information to areas known to contain grid cells – a cell type considered very important in keeping track of one's position in one's surroundings, much like a GPS system.

"It was extremely exciting to actually see these cells and their connections under the microscope for the first time", says Dr. Burgalossi. "They had been a scientific ghost for such a long time." The cells whose discovery so elates the Tübingen neuroscientist are called HD cells. Their existence was stipulated in the early 1990s, including their function: HD cells recognise the head's current angle and facing, a simple yet essential part of recognising one's place in space, and thus of navigation.

But until now, HD cells and their connections with other brain areas had not been identified and observed. The Tübingen researchers were the first to successfully identify them in rats' brains and observe them microscopically. The researchers found their target by inserting hair-thin glass electrodes into the presubiculum, a brain area that had been previously shown to contain HD cells. These electrodes detected the small electrical impulses in the cell they were attached to, generated whenever the rat was facing a particular direction. The presubiculum consists of several layers, which contain different types of neurons. Not all of them are HD cells. "HD cells have a specific morphology and are predominantly found in layer 3 of the presubiculum. We found no HD cells in layer 2, where the neurons also look different", Burgalossi explains, "now we have proven that there is a strong relationship between structure and function.” This structure-function relationship can be considered the holy grail of neuroscience, as it allows researchers to not only say ‘this part of the brain does that’, but also lets them gain insights into how the individual neurons do their job.

Moreover, the researchers’ work provides the first piece of evidence that could explain how HD cells forward information from the presubiculum to other brain areas concerned with navigation. In the brain, networks are formed by axons, long and extremely thin appendages that allow neurons to connect to each other. Axons are the ‘wiring’ that makes up the brain’s ‘circuitry’. They can grow to several millimeters in length even in the tiny brains of rodents, while being only about one micrometer in diameter. These dimensions are also the reason why it is so hard to collect direct evidence of network connections between brain structures. Identifying individual neurons under the microscope is done by injecting dyes into the cell body. But neurons are so thin and their axons can be so long that this is no guarantee one actually gets to see one: “The difficult part of our job is often the labeling procedures” says Burgalossi. “Only if you can efficiently fill a HD cell with dye will you be able to find out which specific neuron – among the many different types in the brain – you have before you, and discover where it projects”.

The team found that HD cells in the presubiculum feed information into the medial entorhinal cortex (MEC), a brain area attracting much attention in neuroscience: this is where the fabled ‘grid cells’ are located, a recently discovered type of neuron that got its name from the way its activity forms a very regular ‘grid-map’ of the environment. The discovery of grid cells earned the Norwegian scientist couple Edvard and May-Britt Moser the Nobel Prize in Physiology or Medicine in 2014. The Tübingen neuroscientists’ new results provide the first anatomical evidence of how the entorhinal grid cell area might be functionally connected to the rest of the brain’s navigational apparatus, in particular with HD cells. Neuroscience is one step closer to understanding the inner compass now.

Publication:
Patricia Preston-Ferrer, Stefano Coletta, Markus Frey, Andrea Burgalossi: Anatomical Organization of Presubicular Head-Direction Circuits. eLife. 10 June 2016. pii: e14592.
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Contact the Author: andrea.burgalossi@cin.uni-tuebingen.de

Press Contact CIN:
Dr. Paul Töbelmann
University of Tübingen
Science Communication and Public Outreach
Werner Reichardt Centre for Integrative Neuroscience (CIN)
Otfried-Müller-Str. 25 · 72076 Tübingen
Tel.: +49 7071 29-89108
paul.toebelmann@cin.uni-tuebingen.de

www.cin.uni-tuebingen.de